4. Butte Water District

This section of the Feather River Regional AWMP contains plan components specific to Butte Water District (BWD).

4.1 Table of Contents

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4.2 Introduction

Since Butte Water District (BWD or District) serves less than 25,000 acres[1] and no funding has been provided for Agricultural Water Management Plan (AWMP or Plan) development, the District is not legally required to update their AWMP. Sections of this AWMP were voluntarily updated, at the District's expense, focusing on updating the historical water budget and efficient water management practices. By updating this AWMP, BWD is actively participating in local, regional, and statewide water management activities, as described throughout this AWMP. This AWMP has been prepared by BWD in accordance with the requirements of the Water Conservation Act of 2009 (SBx7-7) and Agricultural Water Measurement Requirements under Title 23 of the California Code of Regulations (CCR), §597 *et seq.*, 2011. Most, but not all, of the requirements of Assembly Bill 1668 (May 31, 2018) are included in the AWMP.

In 2009, SBx7-7 modified Division 6 of the California Water Code (CWC or Code), adding Part 2.55 (commencing with §10608) and replacing Part 2.8 (commencing with §10800), with the overarching goal of improving water use efficiency. Among its provisions, SBx7-7 allowed the California Department of Water Resources (DWR) to update the efficient water management practices (EWMPs) that suppliers must implement[2], and led to the passage of agricultural water measurement regulations. SBx7-7 also required agricultural water suppliers to prepare and adopt an updated AWMP, as set forth in the CWC and the California Code of Regulations (CCR), every five years, beginning with a Plan adopted on or before December 31, 2015.

AB 1668 modifies Water Code §531.10 *et seq.* and Water Code §10820 *et seq.* to address water conservation issues more adequately and to improve the management and evaluation of agricultural water suppliers' systems. Specifically, AB 1668 requires updated AWMPs to:

(1) include an annual water budget (CWC §10826(c)),
(2) identify water management objectives (CWC §10826(f)),
(3) quantify water use efficiency (CWC §10826(h)), and
(4) revise the supplier's Drought Plan to describe both drought resilience planning and drought response planning (CWC §10826.2).

AB 1668 also modifies AWMP submittal and compliance requirements, requiring the updated AWMP to be submitted to DWR on or before April 1, 2021 (no later than 30 days after adoption), and thereafter on or before April 1 in the years ending in six and one. While not intentionally updating this Plan to comply with AB1668, most requirements of the Bill are satisfied herein.

The main resources used to develop this 2020 AWMP were the CWC itself, the draft 2020 AWMP Guidebook, and the relevant sections of the CCR. A cross-reference table is provided on the

[1] Between 1999 and 2019, the District has served an average of about 15,000 irrigated acres per year.
[2] Critical EWMPs must be implemented by all agricultural water suppliers. Conditional EWMPs must be implemented if they are locally cost-effective and technically feasible.

following pages that identifies the location(s) in the AWMP where each applicable requirement of SBx7-7 and the corresponding sections of the CWC and CCR, is addressed. Although compliance with the law is not required for this voluntary AWMP update, this cross-reference is intended to support efficient review of the AWMP in comparison to requirements of the Law.

4.3 AWMP Checklist

Table 4.1 provides a cross-reference of the requirements of the California Water Code (CWC) to the AWMP sections contained herein.

Table 4.1. Cross-Reference of BWD 2020 AWMP to Relevant Sections of the California Water Code (CWC).

AWMP Section	AWMP Guidebook Location	Description	Water Code Section (or as identified)
N/A	1.4	AWMP Required?	10820, 10608.12
N/A	1.4	At least 25,000 irrigated acres	10853
II.4.2, II.4.4.1, II.4.5.2	1.4	10,000 to 25,000 acres and funding provided	10853
II.4.2, II.4.4, II.4.10.1	1.4	April 1, 2021 update	10820 (a)
II.4.2, II.4.4, II.4.10.1	1.4 A.2	**Added to the Water Code:** <u>Added to the Water Code: AWMP submitted to DWR no later than 30 days after adoption; AWMP submitted electronically</u>	**New to the Water Code:** <u>10820(a)(2)(B)</u>
II.4.2, II.4.4	1.4 B	5-year cycle update	10820 (a)
N/A	1.4 B	New agricultural water supplier after December 31, 2012 - AWMP prepared and adopted within 1 year	10820 (b)
N/A	1.6, 5	USBR water management/conservation plan:	10828(a)
N/A	1.6, 5.1	Adopted and submitted to USBR within the previous four years, AND	10828(a)(1)
N/A	1.6, 5.1	The USBR has accepted the water management/conservation plan as adequate	10828(a)(2)
I, II.4	1.4 B	UWMP or participation in area wide, regional, watershed, or basin wide water management planning: does the plan meet requirements of SB X7-7 2.8	10829

AWMP Section	AWMP Guidebook Location	Description	Water Code Section (or as identified)
II.4.9.1, II.4.4.3, II.4.6.3	3.1A	Description of previous water management activities	10826(d)
II.4.4, II.4.10.1	3.1 B.1	Was each city or county within which supplier provides water supplies notified that the agricultural water supplier will be preparing or amending a plan?	10821(a)
II.4.4, II.4.10.1	3.2 B.2	Was the proposed plan available for public inspection prior to plan adoption?	10841
II.4.4, II.4.10.1	3.1 B.2	Publicly-owned supplier: Prior to the hearing, was the notice of the time and place of hearing published within the jurisdiction of the publicly owned agricultural water supplier in accordance with Government Code 6066?	10841
II.4.4, II.4.10.1	3.1 B.2	14 days notification for public hearing	GC 6066
II.4.4, II.4.10.1	3.1 B.2	Two publications in newspaper within those 14 days	GC 6066
II.4.4, II.4.10.1	3.1 B.2	At least 5 days between publications? (not including publication date)	GC 6066
N/A	3.1 B.2	Privately-owned supplier: was equivalent notice within its service area and reasonably equivalent opportunity that would otherwise be afforded through a public hearing process provided?	10841
II.4.4, II.4.10.1	3.1 C.1	After hearing/equivalent notice, was the plan adopted as prepared or as modified during or after the hearing?	10841
II.4.4, II.4.10.1	3.1 C.2	Was a copy of the AWMP, amendments, or changes, submitted to the entities below, no later than 30 days after the adoption?	10843(a)
II.4.4, II.4.10.1	3.1 C.2	The department.	10843(b)(1)
II.4.4, II.4.10.1	3.1 C.2	Any city, county, or city and county within which the agricultural water supplier provides water supplies.	10843(b)(2)

AWMP Section	AWMP Guidebook Location	Description	Water Code Section (or as identified)
II.4.4, II.4.10.1	3.1 C.2	Any groundwater management entity within which jurisdiction the agricultural water supplier extracts or provides water supplies.	10843(b)(3)
II.4.4, II.4.10.1	3.1 C.3	Adopted AWMP availability	10844
II.4.4, II.4.10.1	3.1 C.3	Was the AWMP available for public review on the agricultural water supplier's Internet Web site within 30 days of adoption?	10844(a)
II.4.4, II.4.10.1	3.1 C.3	If no Internet Web site, was an electronic copy of the AWMP submitted to DWR within 30 days of adoption?	10844(b)
II.4.9	3.1 D.1	Implement the AWMP in accordance with the schedule set forth in its plan, as determined by the governing body of the agricultural water supplier.	10842
II.4.5	3.3	Description of the agricultural water supplier and service area including:	10826(a)
II.4.5.2	3.3 A.1	Size of the service area.	10826(a)(1)
II.4.5.2, II.4.5.3	3.3 A.2	Location of the service area and its water management facilities.	10826(a)(2)
II.4.5.4	3.3 A.3	Terrain and soils.	10826(a)(3)
II.4.5.5	3.3 A.4	Climate.	10826(a)(4)
II.4.5.6, II.4.10.2	3.3 B.1	Operating rules and regulations.	10826(a)(5)
II.4.5.7, II.4.10.3	3.3 B.2	Water delivery measurements or calculations.	10826(a)(6)
II.4.5.8	3.3 B.3	Water rate schedules and billing.	10826(a)(7)
II.4.5.9, II.4.10.4	3.3 B.4	Water shortage allocation policies and detailed drought plan	10826(a)(8) 10826.2
II.4.7.3	3.4	Water uses within the service area, including all of the following:	10826(b)(5)
II.4.7.3	3.4 A	Agricultural.	10826(b)(5)(A)
II.4.7.3	3.4 B	Environmental.	10826(b)(5)(B)

AWMP Section	AWMP Guidebook Location	Description	Water Code Section (or as identified)
II.4.7.3	3.4 C	Recreational.	10826(b)(5)(C)
II.4.7.3	3.4 D	Municipal and industrial.	10826(b)(5)(D)
II.4.7.3	3.4 E	Groundwater recharge, including estimated flows from deep percolation from irrigation and seepage	10826(b)(5)(E)
II.4.6	3.5 A	Description of the quantity of agricultural water supplier's supplies as:	10826(b)
II.4.6.2	3.5 A.1	Surface water supply.	10826(b)(1)
II.4.6.3	3.5 A.2	Groundwater supply.	10826(b)(2)
II.4.6.4	3.5 A.3	Other water supplies, including recycled water	10826(b)(3)
II.4.7.4	3.5 A.4	Drainage from the water supplier's service area.	10826(b)(6)
II.4.6.5	3.5 B	Description of the quality of agricultural waters suppliers supplies as:	10826(b)
II.4.6.5	3.5 B.1	Surface water supply.	10826(b)(1)
II.4.6.5	3.5 B.2	Groundwater supply.	10826(b)(2)
II.4.6.5	3.5 B.3	Other water supplies.	10826(b)(3)
II.4.6.5	3.5 C	Source water quality monitoring practices.	10826(b)(4)
II.4.7, II.4.7.5	3.6	**Added to Water Code:** Annual water budget based on the quantification of all inflow and outflow components for the service area.	**Added to Water Code** 10826(c)
N/A	3.7 C	**Added to Water Code:** Identify water management objectives based on water budget to improve water system efficiency	**Added to Water Code** 10826(f)
N/A	3.8 D	**Added to Water Code** Quantify the efficiency of agricultural water use	**Added to Water Code** 10826(h)
II.4.8	3.9	Analysis of climate change effect on future water supplies analysis	10826(d)

AWMP Section	AWMP Guidebook Location	Description	Water Code Section (or as identified)
II.4.9	4	Water use efficiency	10826(e)
II.4.9		Information required pursuant to § 10608.48.	
II.4.9	4.1	Implement efficient water management practices (EWMPs)	10608.48(a)
II.4.9.1	4.1 A	Implement Critical EWMP: Measure the volume of water delivered to customers with sufficient accuracy to comply with subdivision (a) of §531.10 and to implement paragraph (2).	10608.48(b)
II.4.9.1	4.1 A	Implement Critical EWMP: Adopt a pricing structure for water customers based at least in part on quantity delivered.	10608.48(b)
II.4.9.1	4.1 B	Implement additional locally cost-effective and technically feasible EWMPs	10608.48(c)
II.4.9.1	4.1 C	If applicable, document (in the report) the determination that EWMPs are not locally cost-effective or technically feasible	10608.48(d)
II.4.9.1	4.1 C	Include a report on which EWMPs have been implemented and planned to be implemented	10608.48(d)
II.4.9.2	4.1 C	Include (in the report) an estimate of the water use efficiency improvements that have occurred since the last report, and an estimate of the water use efficiency improvements estimated to occur five and 10 years in the future.	10608.48(d)
N/A	5	USBR water management/conservation plan may meet requirements for EWMPs	10608.48(f)
N/A	6 A	Lack of legal access certification (if water measuring not at farm gate or delivery point)	CCR§597.3(b)(2)(A)
N/A	6 B	Lack of technical feasibility (if water measuring not at farm gate or delivery point)	CCR§597.3(b)(1)(B), §597.3(b)(2)(B)

AWMP Section	AWMP Guidebook Location	Description	Water Code Section (or as identified)
N/A	6 A, 6 B	Delivery apportioning methodology (if water measuring not at farm gate or delivery point)	CCR§597.3.b(2)(C),
II.4.10.3	6 C	Description of water measurement BPP	CCR §597.4(e)(2)
II.4.10.3	6 D	Conversion to measurement to volume	CCR §597.4(e)(3)
II.4.10.3	6 E	Existing water measurement device corrective action plan? (if applicable, including schedule, budget and finance plan)	CCR §597.4(e)(4))

4.4 Plan Preparation and Adoption

4.4.1 Regulatory Compliance

Since BWD serves less than 25,000 acres[3] and no funding has been provided for Agricultural Water Management Plan (AWMP or Plan) development, the District is not legally required to update their AWMP. However, as described previously, this AWMP has been prepared in accordance with the Water Conservation Act of 2009 (SBx7-7) and Agricultural Water Measurement requirements established in Title 23 of the California Code of Regulations (CCR), §597 et seq. Additionally, most, but not all, of the requirements of Assembly Bill 1668 (May 31, 2018) are included in the AWMP. BWD is, at their own expense, voluntarily electing to update their AWMP.

4.4.2 Public Participation and Adoption

Requirements of the CWC and Government Code 6066 related to public review and adoption of AWMPs include the following:

- CWC §10821(a) – An agricultural water supplier required to prepare an AWMP must notify each city or county within which it supplies water that the AWMP will be prepared.
- CWC §10841 – Prior to adopting an AWMP, agricultural water suppliers must make the plan available for public inspection and hold a public hearing. Prior to the hearing, notice of the time and place must be published within the supplier's jurisdiction pursuant to Section 6066 of the Government Code.
- Government Code §6066 – Publication of notice shall be once a week for two successive weeks in a newspaper of general circulation.
- CWC §10843 – A copy of the adopted AWMP must be provided to the following entities within 30 days of the date of adoption:

[3] Between 1999 and 2019, the District has served an average of about 15,000 irrigated acres per year.

  - The California Department of Water Resources (DWR),
  - Any city or county within which the supplier provides water,
  - Any groundwater management entity within which the supplier extracts or supplies water,
  - Any urban water supplier within which the supplier provides water,
  - Any city or county library within which the supplier provides water,
  - The California State Library, and
  - Any local agency formation commission serving a county within which the supplier provides water.
- CWC §10844 – Within 30 days of the date of adoption, the supplier must make the AWMP available on its website (if applicable), or submit an electronic copy to be made available by DWR.

The public participation and adoption process for BWD is documented in Section 4.10.1.

4.4.3 Regional Coordination

This AWMP was originally developed as part of the Feather River Regional AWMP (FRRAWMP), which was funded by a Proposition 204 grant awarded by DWR to the Northern California Water Association (NCWA). Development of the plan included coordination among the following Feather River water suppliers and water management entities:

- Joint Water Districts
  - Biggs – West Gridley Water District (BWGWD)
  - Butte Water District (BWD)
  - Richvale Irrigation District (RID)
  - Sutter Extension Water District (SEWD)
- Western Canal Water District (WCWD)
- Lower Feather Water Users
  - Feather Water District (FWD)
  - Garden Highway Mutual Water Company (GHMWC)
  - Plumas Mutual Water Company (PMWC)
  - Tudor Mutual Water Company (TMWC)
  - Sutter Butte – Butte Slough Water Users Association

Additionally, development of the FRRAWMP included consultation with representatives of the Butte County Department of Water and Resource Conservation, the California Department of Fish and Wildlife, the U.S. Fish and Wildlife Service, and the DWR Northern Region.

The preparation of a regional AWMP for the Feather River region provides the opportunity to evaluate water management within the region as a whole and exposes interdependencies between agricultural water suppliers and other water uses, including other agriculture in the region and terrestrial and aquatic ecosystems. Water use in the region can be described as “cascading” where water diverted and applied on an individual farm or within an individual supplier service area that is not consumed to produce crops or habitat vegetation moves down through the system and remains available for other beneficial uses.

This 2020 update to BWD's AWMP has been prepared by BWD and builds upon and updates the 2016 AWMP, originally part of the 2014 FRRAWMP.

4.5 Background and Description of Service Area

4.5.1 History and Organization

Butte Water District (BWD or District) was originally proposed, organized, and formed in 1952, with the hope that it would begin operation for the 1953 irrigation season. As Richvale Irrigation District (RID), Biggs-West Gridley Water District (BWGWD), and Sutter Extension Water District (SEWD) had individually done during their formation in previous years, BWD would purchase a percentage of the Sutter-Butte Canal Company's water rights and canal system. The Butte County Board of Supervisors held hearings on whether or not to grant permission to an organizing committee to form BWD, but representatives of private ditch companies that would be included in BWD protested over the payment of a service fee that they had paid to the Sutter-Butte Canal Company that would be continued after the formation of BWD. Although the district was formed in 1952, these protests led to a delay in issuing bonds in order to finance the operation of BWD. On April 10, 1956, another revenue bond election was held to purchase the remainder of the Sutter-Butte Canal Company's canal system and pre-1914 water rights, which expanded the area within the BWD service area. Following this expansion of BWD, the Sutter-Butte Canal Company was liquidated in 1957, and RID, BWGWD, BWD, and SEWD organized to form the Joint Water Districts Board (Joint Districts) to coordinate their efforts in managing the Sutter-Butte Canal Company distribution system which they all shared a portion of (McGee 1980). In 1969, the Joint Districts entered into a settlement agreement with the State regarding their water right for the diversion of up to 555,000 af from the Feather River at the Thermalito Afterbay following its construction and the construction of Lake Oroville as part of the State Water Project (Joint Board 1969). BWD currently contains approximately 27,000 acres of irrigable land within its 32,000 acre service area, of which approximately 15,000 acres have been served by the district in recent years[4]. The remaining irrigable lands rely primarily on private groundwater pumping for irrigation.

BWD is a California Water District responsible for providing irrigation water to agricultural water users within its service area. Since before its formation, a variety of crops have been grown within the district's service area. The main crops are orchards, consisting primarily of walnuts and almonds in recent years. Orchards make up over 50% of the irrigable acreage served by the District and approximately 57% of irrigable lands in the BWD service area, including areas relying solely on groundwater for irrigation.

[4] Based on annual reports of the Joint Districts Board. Excludes fallowed acres.

BWD is entitled to approximately 133,000 af of the Joint Districts allowed diversions from the Feather River under its 1969 agreement with the State, which is based on a pre-1914 water right and subject to reduction under certain conditions, as described below.

The District is divided into four divisions and is represented by a board of directors made up of five members. Each director is elected for a four-year term by landowners within the district. The board of directors elect a board president to run the meetings, a vice-president to serve if the board president is unavailable, and a board treasurer. The general manager is principal administrative officer of the district and serves as secretary to the board of directors.

Currently, there are seven full-time district employees. They include the general manager, office assistant, operations manager, three system operators, and a maintenance staff person. The staff additionally perform winter maintenance activities outside of the irrigation season and run fall and winter water deliveries for rice straw decomposition, waterfowl and shorebird habitat, and in some cases orchard irrigation beginning in October and continuing through February or March in some years. An organizational chart of the district is provided in Figure 4.1 (the maintenance staff person is not shown on the chart).

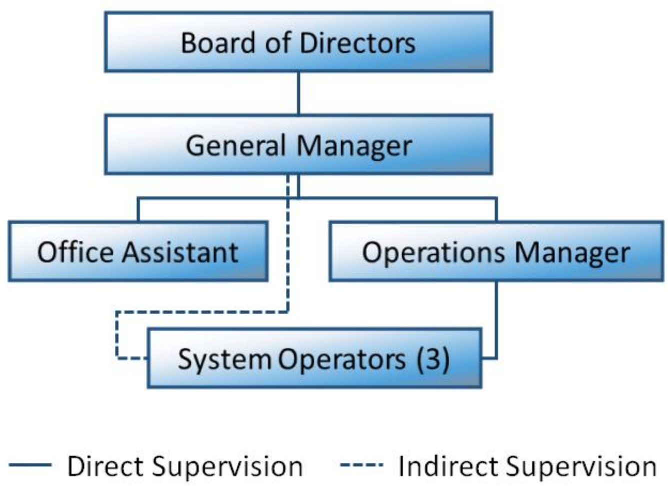

Figure 4.1. Organizational Chart.

4.5.2 Size and Location of Service Area

BWD is located in the Sacramento Valley south of Thermalito Afterbay, west of the Feather River, and northeast of the Sutter Buttes. The cities of Biggs and Gridley lie within the district along its western boundary, with BWGWD to the west of the boundary (Figure 4.2). The district is bounded on the north by Thermalito Afterbay and on the east by the Feather River. The boundary between Butte County and Sutter County divides BWD, with the northern portion in Butte County and southern portion in Sutter County. There are several internal "islands" of land surrounded by BWD that are not included within the district service area. One of these includes the city of Live Oak. Approximately 15,700 acres within the service area are planted to orchards, and 7,400 acres are planted to rice. The remaining cropland is a mixture of pasture, and row crops. However, portions of this irrigated area are dependent solely on groundwater; on average, BWD delivers water to about 15,000 irrigated acres per year.

The location of BWD's service area relative to the Sacramento Valley as a whole and the Feather River Region is shown in Volume 1, Section 2 of this AWMP.

4.5.3 Distribution and Drainage System

The BWD distribution system is shown in Figure 4.2. The figure shows the service area and surrounding areas, irrigation and drainage facilities, other waterways (including natural waterways), and points of inflow and outflow from the district.

The main and lateral distribution system is an open, gravity flow system and is operated via upstream level control. Daily diversions are adjusted through coordination with the Joint Districts manager who in turn coordinates releases with DWR operators of Thermalito Afterbay. Water level fluctuations in the afterbay result in fluctuations in releases to BWD and the other Joint Districts which are propagated through the districts' distribution systems to varying degrees.

Water is conveyed by the canal and lateral system through a series of control structures used to maintain desired upstream water levels, subject to certain physical and operational constraints. This enables consistent gravity delivery through turnouts. At the ends of the laterals are safety spills or "safeties," which are used to convey operational spillage into drains and sloughs and to deliver water to downstream water users in some cases.

Water is diverted into BWD from the Thermalito Afterbay via the Sutter-Butte Canal. The Sutter-Butte Canal is owned collectively by the Joint Water Districts but flows south directly through Butte Water District, and is operated by Butte Water District staff south of the Looney Gates. The canal serves as the main canal for the BWD distribution system. The Sutter-Butte Canal has a capacity of approximately 800 cfs and a length of approximately 16 miles within BWD. Water is delivered from the Sutter-Butte Canal into district facilities including individual turnouts and private ditches on the Canal and to BWD operated and maintained laterals. Primary laterals supplied by the Sutter-Butte Canal include Lateral 4 (capacity of 80 cfs) and Chandon Lateral (capacity of 200 cfs); the District has installed flow measurement and SCADA equipment at both of these lateral headings in recent years. The BWD distribution system includes 17 laterals totaling about 42 miles in length. For the period 1999 to 2019, BWD received between approximately 87,000 af and 133,000 af to serve district customers[5]. The average annual diversion for this period was 107,000 af. Annual

[5] Expressed on a water year basis (October – September) based on reports of the Joint Districts Board. Deliveries to other districts through the Sutter-Butte canal including RID, BWGWD, and SEWD are excluded. Estimated conveyance losses within the Sutter Butte Canal incurred from serving other districts that are not accounted for against BWD's allotment are also excluded. Total annual diversions may exceed the District's 133,000 af entitlement in part due to non-allotted winter diversions for wildlife habitat and rice straw decomposition.

diversions depend upon a combination of factors, including demands from the district's customers and infrequent reductions resulting from the district's settlement agreement with the State.

Within BWD, the Sutter-Butte Canal includes 12 primary control structures, four of which are automated. Deliveries are made to fields at approximately 580 individual turnouts. There are approximately 20 miles of primary drains within BWD; in two locations, drainwater recovery pumps are installed and drainwater can be recovered and reused. It is also estimated that there are in excess of 100 miles of secondary drains that carry water to primary drains and natural waterways. Excess system flows in the distribution system, if present, can be released from the system at approximately 20 safety spills or "safeties". Many of the safeties additionally serve as delivery points for downstream water users which lie downgradient of the existing distribution system and pump delivered water from the drains.

Unlike the other Joint Districts, a substantial portion of water provided by BWD to its customers is delivered through privately-owned ditches maintained by groups or associations of landowners.

BWD also owns two groundwater wells in Sutter County in the southern portion of the district that have been used for groundwater substitution water transfers. The wells could also be used to supplement surface water supplies but have not been used for this purpose historically.

The district is divided into four operational divisions. The divisions operate under the supervision of the operations manager and general manager. Within divisions, actual field operations are executed by the three system operators (the operations manager is also responsible for the fourth division). Division sizes average approximately 4,100 acres. The divisions have been delineated to achieve uniform division of workloads among operators.

Drainage in BWD occurs through both naturally occurring waterways and man-made drains, which all flow to the west or south. Drains in the northern part of the district are operated and maintained by Reclamation District 833 (RD833) and tend to flow west. Drains and sloughs include Hamilton Drain, Meyers Drain, and Brooks Drain. Drainage in the southern portion of the district tends to flow south; there are three reclamation districts that operate and maintain drains within BWD flowing south. From the west to the east, they are Reclamation District 2054 (RD2054), Reclamation District 2056 (RD2056), and Reclamation District 777 (RD777). Natural waterways and sloughs that collect surface drainage from man-made drains and convey it to the south through BWD include Snake Creek, Morrison Slough, and Live Oak Slough.

The distribution system and drainage systems within BWD are integrated. For example, there are 2 recycle pumps located within the district where water can be lifted out of drains and put back into the distribution system for downstream use, although they are seldom used, as drain water is relied upon as a source of supply by downstream growers within the district. Drains and natural waterways primarily purposed to provide drainage. There are locations within BWD where water is also delivered into drains or natural sloughs intentionally for downstream irrigation use. In most of these cases, the downstream grower uses a private lift pump to lift water to their fields for irrigation. The irrigation and drainage system consists primarily of unlined ditches, although pipelines have been installed in areas with seepage problems, as described later in this section.

As described previously, cropping in BWD consists of a combination of orchards, rice, row crops, and pasture. BWD's delivery practices have been established to best suit the needs of its customers. For orchards and other non-ponded crops grown in the district, a combination of pressurized and surface irrigation methods are used, and delivery requests are filled on a rotational basis or on an arranged-demand basis, as practical. Orders are generally filled with a minimum of 24-hours lead time, but are often filled with less lead time when operational constraints allow. For rice, water has historically been delivered on an arranged-demand basis for flood up in the spring. Growers place orders directly with system operators, and water deliveries are generally made in the sequence received, subject to operational constraints. Once rice is established, continuous deliveries are made as needed to maintain rice pond levels (except when deliveries are ceased and water is held or drained to support chemical applications), with potential periodic adjustments to match crop evapotranspiration and deep percolation rates while limiting tailwater outflow. For additional detail describing water management objectives for rice production, see Volume I, Section 4 of this AWMP.

The irrigation season generally begins in April or May. Deliveries and associated diversions typically decrease from August to September in preparation for harvest. Fall and winter deliveries for rice decomposition and waterfowl habitat, of which there are relatively few in BWD, begin in October and continue through January. Between 1999 and 2019, deliveries were between 48,000 and 97,000 af with an average of 76,000 af. Over this period, deliveries display a decreasing trend with a 1999-2009 average of 85,000 af and a 2010-2019 average of 65.000 af. Reductions in deliveries over time are due to several factors, including increased urbanization in the greater Biggs, Gridley, and Live Oak areas; orchard growers converting from flood irrigation using surface water to pressurized irrigation such as microspray and drip using groundwater or less surface water; and water transfers reducing surface water demand. Deliveries during the fall and winter between 1999 and 2019 have fluctuated from year to year but generally increased over this period. One factor resulting in increased winter deliveries is the passage of the Connelly-Areias-Chandler Rice Straw Burning Reduction Act of 1991, which phased out rice straw burning, except under special circumstances, between 1992 and 2001. As an alternative, rice straw is now commonly decomposed via winter flooding between October and January, which also provides important habitat benefits for migratory waterfowl and shorebirds.

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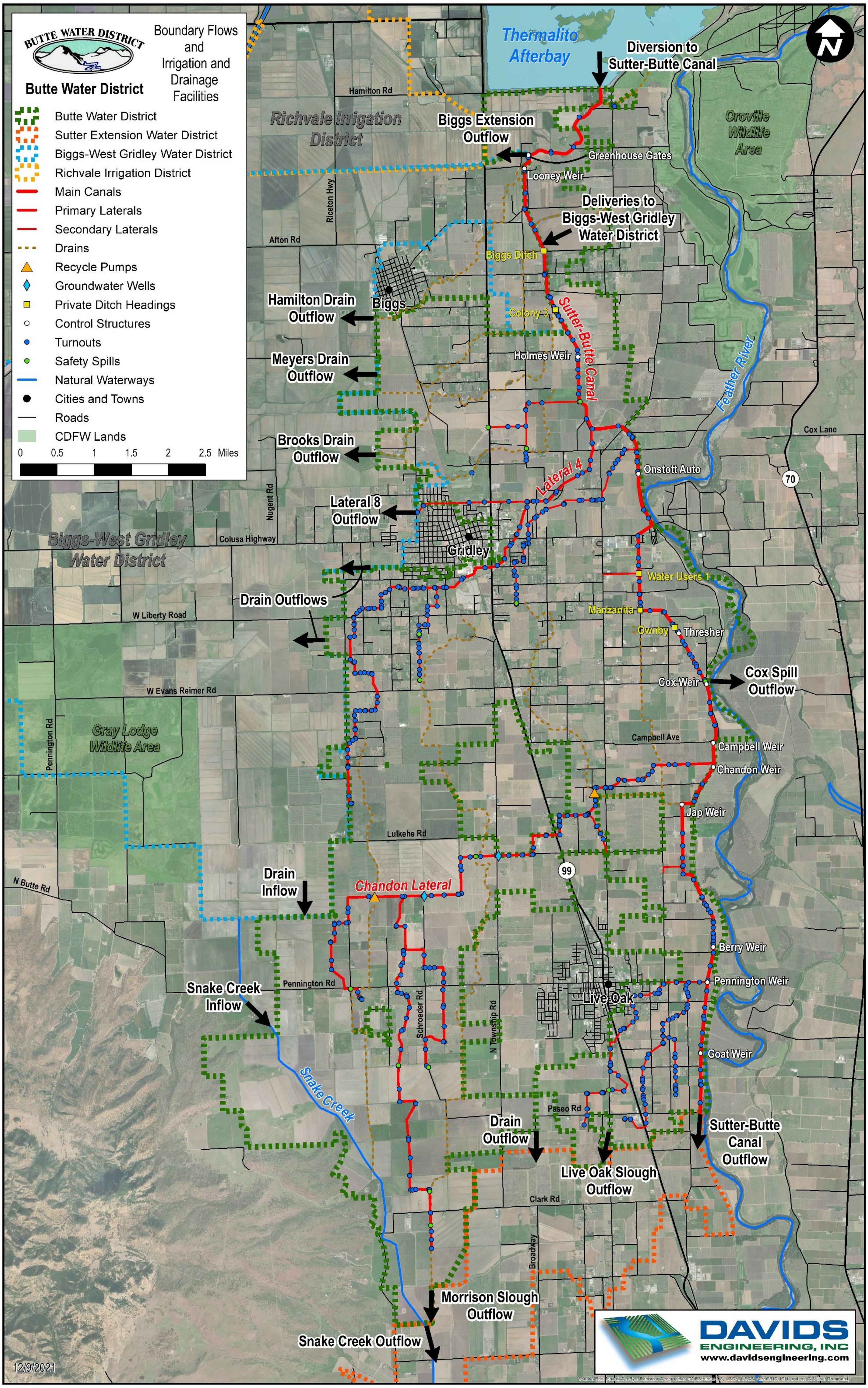

Figure 4.2. Boundary Flows and Irrigation and Drainage Facilities.

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4.5.4 Terrain and Soils

Located on the Sacramento Valley floor, BWD's topography is generally flat. Land surface elevation varies from approximately 110 feet above mean sea level in the northern portion of the District to about 70 feet in the south. The land falls to the south at approximately 0.5 feet per thousand feet (0.05 percent) on average. Accordingly, drainage within the district generally flows to the south through the RD2054, RD2056, and RD777 drains and natural waterways and sloughs such as Snake Creek, Morrison Slough, and Live Oak Slough. It is worth noting that there is an area in the northern portion of the district where drainage flows west into BWGWD towards Butte Creek.

Soils underlying over half of the land within the District are identified as loamy alluvium. Most of the remaining land is underlain by either clayey alluvium or a mixture of clayey alluvium and loamy alluvium. A total of 13 soil map units, as defined by the Natural Resources Conservation Service (NRCS 2006a, 2009b), comprise approximately 91 percent of the irrigated area. Characteristics of these map units are summarized in Table 4.2. For the soils characterized as loamy alluvium, available water holding capacity is typically five to fifteen inches in the top five feet, and the soils are moderately well drained with varying saturated hydraulic conductivity (i.e., permeability). For soils characterized as clayey alluvium, available water capacity is typically between three and seven inches in the top five feet, and the soils are poorly drained with very low saturated hydraulic conductivity. Sand lenses exist in some areas, allowing for preferential flow between the surface water and groundwater systems. The depth to shallow groundwater, where present, is typically between zero and six feet. Soil characteristics vary from being well suited for orchard and other non-ponded crops to being well suited for rice. The spatial distribution of cropping is consistent with soil suitability.

Table 4.2. Characteristics of Dominant Soils in Butte Water District.

Soil Map Unit	Percent of Area	Land-form(s)	Slope Range	Parent Material	Available Water Holding Capacity	Drainage	Saturated Hydraulic Conductivity Class	Restrictive Layer	Depth to Water Table	Typical Profile[1]	
Boga-Loemstone Complex	21%	terraces on valleys	0 to 1 percent	loamy alluvium over dense silty alluvium	9.5 to 14.5 inches in top 5 feet	moderately well drained	low	dense material at 40 to 80 inches	35 to 72 inches	0 - 6 inches:	loam
										6 - 53 inches:	clay loam
										53 - 73 inches:	loam
										73 - 80 inches:	dense material
Gridley Taxadjunct Loam	12%	terraces on valleys	0 to 2 percent	loamy and clayey alluvium over cemented loamy alluvium	3.9 inches in top 5 feet	somewhat poorly drained	very low	duripan at 20 to 40 inches	15 to 20 inches	0 - 10 inches:	loam
										10 - 20 inches:	clay loam
										20 - 22 inches:	clay loam
										22 - 60 inches:	cemented material
Liveoak Sandy Clay Loam	10%	terraces on valleys	0 to 2 percent	channel deposited loamy alluvium	10.0 inches in top 5 feet	moderately well drained	high	none	30 to 65 inches	0 - 53 inches:	sandy clay loam
										53 - 60 inches:	sandy loam
Conejo-Tisdale Complex	9%	terraces on valleys	0 to 2 percent	loamy alluvium	5.4 to 7.1 inches in top 5 feet	well drained	very low	dense material or bedrock at 20 to 60 inches	none within soil profile	0 - 42 inches:	loam
										42 - 46 inches:	weathered bedrock

Soil Map Unit	Percent of Area	Land-form(s)	Slope Range	Parent Material	Available Water Holding Capacity	Drainage	Saturated Hydraulic Conductivity Class	Restrictive Layer	Depth to Water Table	Typical Profile[1]	
Subaco Clay	8%	basin floors on valleys	0 to 2 percent	clayey alluvium	3.9 inches in top 5 feet	poorly drained	moderately low	bedrock at 20 to 40 inches	27 inches	0 - 26 inches:	clay
Tisdale Clay Loam	6%	terraces on valleys	0 to 2 percent	mixed loamy alluvium	5.4 inches in top 5 feet	well drained	very low	bedrock at 20 to 40 inches	none within soil profile	0 - 31 inches:	clay loam
										31 - 35 inches:	bedrock
Oswald Clay	6%	basin floors on valleys	0 to 2 percent	clayey alluvium	5.3 inches in top 5 feet	poorly drained	very low	bedrock at 20 to 40 inches	30 inches	0 - 33 inches:	clay
										33 - 37 inches:	weathered bedrock
Duric Xerarents-Eastbiggs Complex	5%	terraces on valleys	0 to 1 percent	clayey alluvium over cemented loamy alluvium	2.3 to 7.1 inches in top 5 feet	somewhat poorly drained	very low	duripan at 6 to 80 inches	4 inches to more than 60 inches	0 - 10 inches:	clay loam
										10 - 13 inches:	clay
										13 - 60 inches:	cemented material
Liveoak Sandy Loam	4%	terraces on valleys	0 to 2 percent	loamy and sandy alluvium	8.4 inches in top 5 feet	moderately well drained	high	none	30 to 60 inches	0 - 61 inches:	sandy loam
										61 - 71 inches:	sand
										71 - 75 inches:	gravelly sand
Gridley Clay Loam	4%	terraces on valleys	0 to 1 percent	clayey alluvium	6.5 inches in top 5 feet	moderately well drained	moderately low	bedrock at 20 to 40 inches	none within soil profile	0 - 19 inches:	clay loam
										19 - 37 inches:	clay

Soil Map Unit	Percent of Area	Land-form(s)	Slope Range	Parent Material	Available Water Holding Capacity	Drainage	Saturated Hydraulic Conductivity Class	Restrictive Layer	Depth to Water Table	Typical Profile[1]	
Gridley Taxadjunct Clay Loam	3%	terraces on valleys	0 to 2 percent	clayey and loamy alluvium over cemented loamy alluvium	3.9 inches in top 5 feet	somewhat poorly drained	very low	duripan at 20 to 40 inches	15 to 20 inches	0 - 21 inches:	clay loam
										21 - 60 inches:	cemented coarse sandy loam
Gianella Fine Sandy Loam	3%	flood plains on valleys	0 to 1 percent	stratified coarse-loamy alluvium	9.5 inches in top 5 feet	moderately well drained	high	none	80 inches	0 - 12 inches:	fine sandy loam
										12 - 19 inches:	loam
										19 - 28 inches:	fine sandy loam
										28 - 48 inches:	loam
										48 - 57 inches:	sandy loam
										57 - 80 inches:	loamy sand
Marcum-Gridley Clay Loams	2%	terraces on valleys	0 to 1 percent	loamy alluvium	7.4 inches in top 5 feet	moderately well drained	very low	bedrock at 40 to 80 inches	none within soil profile	0 - 28 inches:	clay loam
										28 - 40 inches:	clay
										40 - 43 inches:	clay loam
										43 - 62 inches:	bedrock

1. For complexes, which contain a combination of distinct map units, the typical profile describes the primary map unit.

4.5.5 Climate

The climate statistics presented in this section are based on the Durham CIMIS station (#12) for the period October 1984 to September 2020. The station is located approximately 15 miles north of BWD's service area and considered representative of BWD's climate and the Feather River region as a whole. Monthly climate statistics are summarized in Table 4.3.

BWD has a climate typical of the eastern Sacramento Valley, with mild winters with mild to moderate precipitation and warm to hot, dry summers. Average daily maximum temperatures range from a low of about 55°F in December to a high of approximately 91°F in July. Mean daily minimum temperatures range from a low of approximately 37°F in December and January to a high of about 60°F in July. Average annual reference evapotranspiration (ET_o) is approximately 51 inches, ranging from a low of one inch in December and January to a high of over seven inches in June and July. Approximately 75 percent of annual ET_o occurs in the six-month period from April through September.

Average annual precipitation is approximately 22.7 inches, with 17.3 inches or slightly more than 75 percent occurring in the five month period from November through March.

Even during the peak summer period, the average maximum relative humidity reaches between 80 and 90 percent, which is indicative of an irrigated area, and remains near or above 90 percent throughout the year. Minimum relative humidity ranges between approximately 35 to 40 percent during the summer and roughly 45 to 65 percent during the wet winter months.

Average wind speed is lowest during the summer in August (3.3 miles per hour) and greatest during late winter and early spring during February and March (5.0 five miles per hour).

There are no significant microclimates within the district that affect water management or operations.

Table 4.3. Mean Daily Weather Parameters by Month at Durham CIMIS Station (October 1984 to September 2020).

Month	Total ET_o (in)	Total Precip. (in)	Average Daily Temperature (F)			Average Relative Humidity (%)			Average Wind Speed (mi/hr)
			Avg.	Min.	Max.	Avg.	Min.	Max.	
January	1.2	4.0	45.6	37.2	55.6	80	62	93	4.4
February	2.0	3.7	49.8	39.4	61.4	70	49	89	5.0
March	3.4	3.1	54.1	42.3	66.5	67	44	89	5.0
April	4.8	1.5	59.1	45.6	72.9	61	37	88	4.8
May	6.5	1.2	66.5	52.1	80.5	58	36	87	4.6
June	7.4	0.6	72.5	57.8	86.9	57	34	86	4.3
July	7.7	0.1	75.8	60.3	91.3	60	37	89	3.5
August	6.7	0.1	73.8	58.3	90.3	61	37	90	3.3
September	5.0	0.4	69.8	54.7	87.1	58	33	87	3.5
October	3.4	1.4	61.6	48.0	78.0	60	35	87	3.7
November	1.7	2.7	51.3	40.5	64.3	73	50	92	3.9
December	1.1	3.9	45.0	36.5	54.9	79	61	93	4.5
Annual	**50.8**	**22.7**	**60.4**	**47.7**	**74.1**	**65**	**43**	**89**	**4.2**

4.5.6 Operating Rules and Regulations

The district's operating rules and regulations (R&Rs) are occasionally reviewed and revised as needed to address changing conditions. The R&Rs prescribe conditions that ensure distribution of irrigation water to users in an orderly, efficient, and equitable manner; they are available to water users in pamphlet form and are included at the end of this chapter in Section 4.10.2 for convenient reference.

4.5.7 Water Delivery Measurement and Calculation

BWD measures delivery volumes in a manner sufficient to support effective water management and equitable billing to customers. BWD is below the minimum acreage threshold required for mandatory compliance with the delivery measurement requirements of the Water Conservation Act of 2009 (SBx7-7) and California Code of Regulations Title 23 §597 (CCR 23 §597) and is therefore not subject to the law. The measurement requirements of SBx7-7 state that agricultural water suppliers subject to the law shall measure the volume of water delivered to customers with sufficient accuracy to (1) enable reporting of aggregated farm-gate delivery data to the state, and (2) adopt a pricing structure for water customers based at least in part on the quantity of water delivered. In addition, CCR 23 §597 specifies minimum accuracy requirements for delivery measurement devices and requires certification of volumetric delivery measurement accuracy by a California registered professional engineer.

BWD has evaluated customer delivery measurement options and potential costs that would be incurred if BWD chose to implement volumetric measurement and billing in accordance with SBx7-7 measurement requirements. Modifications to existing delivery infrastructure to support improved delivery measurement may be undertaken over time, subject to funding and project prioritization.

4.5.8 Water Rate Schedules and Billing

Historically, BWD has charged customers for irrigation water deliveries on a flat rate, per-acre basis, plus a stand-by charge. The standby charge, as of 2020, was $5 per acre. Rates are updated periodically by the Board of Directors. The per-acre rates for the 2020 primary irrigation season (i.e., April to October) were $25 per acre for gravity deliveries to orchards or row crops (with a maximum of 8 irrigations), $27 per acre for gravity deliveries to alfalfa, $30 per acre for gravity deliveries to pasture (with a maximum of 15 irrigations), and $36 per acre for gravity deliveries to rice. Due to the large number of small parcels in BWD, there is also a minimum flat rate charge of $80, regardless of acreage. For deliveries via a pump/drain, a 50% discount may be applied depending on irrigation method, and for one-time deliveries a 50% discount may be applied depending on irrigation method. Water is available during the winter period (November to January) at a rate of $12 per acre for gravity deliveries and $6 per acre for pump/drain deliveries.

Additionally, BWD has had an agreement in place in recent years to provide surplus water supplies (if available) to customers outside of its service area in RID at a cost of $9.50 per acre-foot.

Standby assessments are issued in two installments due April 10 and September 10 each year. Two applications for water service, one for summer water and one for winter water, are made annually by customers in the service area and outside of the service area. For each application, the landowner specifies the Farm Service Agency (FSA) Field number, irrigated acreage, and type of irrigation, along with landowner information. Bills are issued at the time of application and are due by April 1 for summer water and before water delivery for winter water. A penalty may be assessed to customers not submitting payment by the specified due date.

4.5.9 Water Shortage Allocation Policies and Drought Management Plan

On April 1, 2015 Governor Brown issued Executive Order B-29-15, mandating agricultural water suppliers to include a detailed Drought Management Plan (DMP) describing actions and measures taken to manage water demand during drought. BWD has historically experienced very reliable surface water supplies with a full surface water supply of approximately 133,000 acre-feet available in all but four years (1977, 1991, 1992, and 2015) since construction of Lake Oroville and its subsequent 1969 settlement agreement with the State. During years in which curtailment is allowed under the agreement, BWD's water supply can be reduced by up to approximately 50 percent, as discussed in greater detail in the attached DMP (Section II.4.10.4).

The DMP describes and expands upon BWD's shortage allocation policies, including discussion of a broad range of actions undertaken during drought to manage available water supplies and meet customer demands to the maximum extent possible. The DMP includes components recommended by DWR in its 2015 AWMP Guidebook (DWR 2015). BWD's DMP describes the determination of available water supply, drought responses, and water shortage impacts. The description of water shortage impacts includes a discussion of 2015 supply and demand conditions available at the time of preparation of this DMP. A description of supplies and demands for 2013 and 2014, also required under Executive Order B-29-15, is included in the water balance section of this AWMP (II.4.7). The DMP was not updated in accordance with AB 1668 in the 2020 AWMP update as the District is voluntarily updating other sections of the Plan.

4.5.10 Policies Addressing Wasteful Use of Water

BWD actively prohibits the wasteful use of water, as described in its R&Rs (Section 4.10.2). Enforcement actions include withholding water for careless, negligent, or willful wasteful use. The district's policies regarding unauthorized uses of water and enforcement are described in detail in the R&Rs. Water use that could be considered waste within the district remains available to provide groundwater recharge or is available for downstream agricultural or environmental water uses; regardless, the district actively prohibits excessive water use.

4.6 Inventory of Water Supplies

4.6.1 Introduction

This section provides a brief description of surface water and groundwater supplies within BWD as well as a description of BWD water quality monitoring practices.

4.6.2 Surface Water Supply

As described in Section 4.5.1, BWD is entitled to approximately 133,000 af of the Joint Districts allowed diversions from the Feather River under its 1969 agreement with the State, which is based on a pre-1914 water right and subject to reduction under certain conditions, as described previously. Additionally, BWD and individual water users within BWD can reuse surface water entering the district via Snake Creek and other minor surface inflows. BWD does not typically utilize this water, as it is utilized and depended on by BWD customers.

4.6.3 Groundwater Supply

BWD overlies portions of the Butte and Sutter subbasins of the Sacramento Valley groundwater basin. Approximately 60% and 40% of the District's service area overlies the Butte and Sutter subbasins, respectively. The water-bearing formations of the Butte subbasin consist of a combination of Holocene, Pleistocene, and Pliocene deposits and alluvium. The water-bearing formations of the Sutter subbasin consist of a combination of Holocene, Pleistocene, Pliocene, Miocene-Pliocene, and Oligocene-Miocene deposits and alluvium. The formations, size, and other features of the subbasins are described in Volume I, Section 2.7.2 of this AWMP.

BWD has a history of actively participating in groundwater management initiatives in the Butte and Sutter subbasins and Butte and Sutter counties as a whole. Most recently, BWD has embarked on the implementation of the Sustainable Groundwater Management Act of 2014 (SGMA) as a local Groundwater Sustainability Agency (GSA). SGMA represents a major shift in the management of California's groundwater resources, allowing local agencies to prepare and adopt Groundwater Sustainability Plans (GSPs) or Alternative Plans tailored to achieving sustainability of underlying groundwater basins and subbasins through local actions. For the Butte and Sutter subbasins, each of which have been designated as medium priority basins under the Law, a GSP, combination of GSPs, or suitable Alternative Plan addressing the entirety of each subbasin separately must be prepared and submitted to DWR. GSPs must be submitted by January 31, 2022, while Alternative Plans must be submitted by January 31, 2017. The following agencies have formed GSAs in the Butte subbasin:

- Colusa Groundwater Authority
- Reclamation District No. 2106
- Reclamation District No. 1004
- City of Gridley
- City of Biggs
- County of Butte
- Western Canal Water District
- Butte Water District
- Biggs-West Gridley Water District
- Richvale Irrigation District
- County of Glenn

The following agencies have formed GSAs in the Sutter subbasin:

- Reclamation District No. 1660
- Reclamation District No. 70
- City of Yuba City
- County of Sutter
- Reclamation District No. 1500
- City of Live Oak
- Sutter Extension Water District
- Sutter Community Service District
- Butte Water District

Moving forward, BWD will actively collaborate with GSAs and eligible interested parties in the subbasins to sustainably manage available groundwater resources. The development and use of surface water supplies by BWD and others over the past century has greatly contributed to the sustainability of the groundwater system through beneficial recharge and prevention of pumping that would otherwise have occurred.

Prior to SGMA, BWD adopted an AB 3030 compliant groundwater management plan (GMP) in 1996 with the purpose of managing and monitoring groundwater resources within the district (BWD 1995). As part of GMP implementation, BWD coordinates and cooperates with other local water management entities to preserve, protect, and monitor groundwater extraction, distribution, and allocation within the basin. Components of BWD's GMP include the following:

- Control of saline water intrusion,

- Identification and management of well head protection areas and recharge areas,
- Regulation of migration of contaminated groundwater,
- Administration of a well abandonment and well destruction program,
- Mitigation of overdraft conditions,
- Replenishment of groundwater extracted by water producers,
- Groundwater level and storage monitoring,
- Development of relationships with State and Federal regulatory agencies,
- Facilitation of conjunctive use operations, and
- Implementation of the groundwater management plan.

Additionally, as a member of the Butte Basin Water Users Association, BWD was a participant in the development of the Butte County GMP finalized in 2004. The Butte County GMP accomplishes the following (CDM 2004):

- Supports the long-term maintenance of high quality groundwater resources within the county for agricultural, environmental, rural domestic and urban needs;
- Documents the county's existing groundwater management programs;
- Describes potential actions to increase the effectiveness of groundwater management; and
- Meet requirements of available grant funding opportunities.

Objectives of the Butte County GMP include the following:

- Minimize the long-term drawdown of groundwater levels,
- Protect groundwater quality,
- Prevent inelastic land surface subsidence resulting from groundwater pumping,
- Minimize changes to surface water flows and quality that directly affect groundwater levels or quality,
- Minimize the effect of groundwater pumping on surface water flows and quality,
- Evaluate groundwater replenishment and cooperative management projects, and
- Provide effective and efficient management of groundwater recharge projects and areas.

In addition to developing the Butte County GMP, the county board of supervisors approved a groundwater management ordinance in 2004 to support the development of quantitative Basin Management Objectives (BMOs). Specific BMOs address the following:

- Groundwater levels,
- Groundwater quality, and
- Inelastic land subsidence,

Additionally, BWD was a participant in the development of the Sutter County GMP finalized in 2012. The Sutter County GMP accomplishes the following (Wood Rogers 2012):

- Provides a publicly available summary of the groundwater system underlying the county and its role in overall water supply,

- Formulates goals and objectives to support management of groundwater to meet current and future demands,
- Establishes a plan for county involvement in ongoing monitoring and management of groundwater, and
- Maintains eligibility for DWR grant funding to increase understanding of the groundwater system.

Goals and BMOs of the Sutter County GMP include the following:

- Groundwater Management Goals
    - Promote responsible groundwater use to sustain the resource,
    - Provide information to support responsible stewardship of the resource,
    - Discourage activities that could reduce long-term availability of high-quality groundwater.
- Basin Management Objectives
    - Groundwater levels,
    - Groundwater quality,
    - Inelastic land subsidence,
    - Surface water,
    - Coordination.

As described in section 4.5, BWD owns two groundwater wells in Sutter County. These wells are used in certain years to increase statewide water supplies through groundwater pumping in lieu of surface water diversions. Private pumping within BWD for irrigation is estimated to have been approximately 23,000 af annually in recent years.

4.6.4 Other Water Supplies

BWD does not have access to water supplies other than those described previously in section 4.6.

4.6.5 Water Quality Monitoring Practices

BWD actively monitors groundwater quality within its service area. BWD monitoring activities as well as other past and ongoing water quality monitoring efforts are described below.

Surface Water

BWD does not actively monitor surface water quality; however, water quality monitoring has been performed in the past by BWD and continues to be performed by other water and resource management entities including DWR, the U.S. Geological Survey, the county, other water suppliers, and through water quality coalitions, as described in the following paragraphs. Surface water and within BWD is of good quality for irrigation and wildlife habitat.

Growers within BWD participate in the Sacramento Valley Water Quality Coalition and/or the California Rice Commission Coalition, which conduct monitoring of surface water quality in compliance with the Central Valley Regional Water Quality Control Board's Irrigated Lands

Regulatory Program (ILRP). The monitoring program includes sampling and testing of a host of parameters for hundreds of samples collected annually from sites strategically distributed throughout the Sacramento River basin, which includes the Feather River region.

BWD is a party to a settlement agreement with DWR and three other districts (BWGWD, RID, and WCWD) that addresses yield losses from lower water temperatures that result from the operation of Lake Oroville, as compared to pre-reservoir conditions. As part of the process to develop the settlement agreement, BWD, DWR, and the other districts developed and implemented a method to estimate rice yield reductions through detailed monitoring of water temperatures and yields.

Groundwater

BWD monitors groundwater quality within its service area at both its two production wells and its dedicated monitoring well. Water quality parameters monitored include electrical conductivity, temperature, pH, TDS, arsenic, and boron. Temperature, pH, and electro conductivity are monitored on a monthly basis when district wells are being operated and somewhat less frequently when they are not in use. Comprehensive testing including TDS, arsenic, and boron are conducted annually in June or July. The water is generally of good quality for irrigation, though elevated arsenic requires mixing of groundwater with Feather River water.

In 2014, NCWA prepared a groundwater quality assessment report for the Sacramento Valley to evaluate the sources of salt and nitrate loads and potential long-term effects on surface water and groundwater resources. This information supports understanding of sustainable management of surface water and groundwater supplies, including conjunctive management opportunities and limitations. The primary objectives of the assessment were to (1) identify where known groundwater quality impacts exist, (2) prioritize high vulnerability areas, and (3) evaluate opportunities to incorporate existing groundwater monitoring efforts to achieve water management objectives.

4.7 Water Balance

4.7.1 Overview

This section describes the various uses of water within BWD between 1999 and 2019, followed by detailed water balances for key accounting centers within the district. Water balances are presented for both the distribution and drainage system (i.e., canals and drains) and farmed lands, and for the district as a whole. The water balances quantify all substantial inflows to and outflows from the BWD service area on a water year basis (October – September). The period from 1999 to 2019 has been chosen because it depicts recent changes in water management as well as current management conditions. Key drivers of water management variability across years include precipitation timing and amounts, crop idling for water transfers, and surface water reductions. Surface water reductions only occurred in one year, 2015, during the period from 1999 to 2019. Conditions in curtailed years are discussed in greater detail in the Drought Management Plan, included as Attachment 4.10.4 of this AWMP.

Historical estimates of water use may differ slightly from those presented in BWD's 2016 AWMP as a result of refinements to the analyses used to develop the estimates, but fall within the range of uncertainty presented in Table 4.4 and do not affect conclusions regarding water management conditions within BWD.

The remainder of this section includes the following subsections:

- Analytical Approach – Description of mass balance approach for water balance analysis, methodologies for estimation of individual flow paths, and uncertainty in flow path estimates;
- Water Uses – Description of water use for agricultural, environmental and recreational, municipal and industrial, groundwater recharge, and transfer and exchange purposes;
- Drainage – Description of drainage occurring within and flowing from the district; and
- Water Accounting (Water Balance Summary) – Summary of monthly and annual inflows to and outflows from the district, including a discussion of existing water management and performance.

4.7.2 Analytical Approach

The BWD water balance includes separate accounting centers for the distribution and drainage system and the farmed lands within the service area. A total of 26 individual flow paths are estimated. A schematic of the water balance structure is provided in Figure 4.3. The schematic identifies sources and destinations of water, accounting centers, and individual flow paths by which water enters and leaves the system.

For BWD, the majority of the water entering the district via the Sutter-Butte Canal is delivered to other members of the Joint Districts or lost in conveyance of the water to other of the Joint Districts and thus unavailable to meet BWD customer demands. As a result, in order to characterize water management by BWD, "allotted diversions" by BWD are presented, which represent total inflows to the Sutter-Butte Canal, minus deliveries to other districts and losses resulting from conveyance to others, including return flows to the Feather River at Cox Spill. Estimated losses from conveyance to SEWD through the Sutter Butte Canal, calculated as 17.6 percent of allotted gravity diversions by SEWD, are reported explicitly as part of the BWD water balance. Cox Spill return flows to the Feather River are reported in the regional water balance (Volume I, Section 4). Additionally, note that BWD's net diversions may exceed estimated water usage by BWD as reported in Joint District hydrology reports due to winter diversions during the non-allotted period from November to March.

Mass Balance

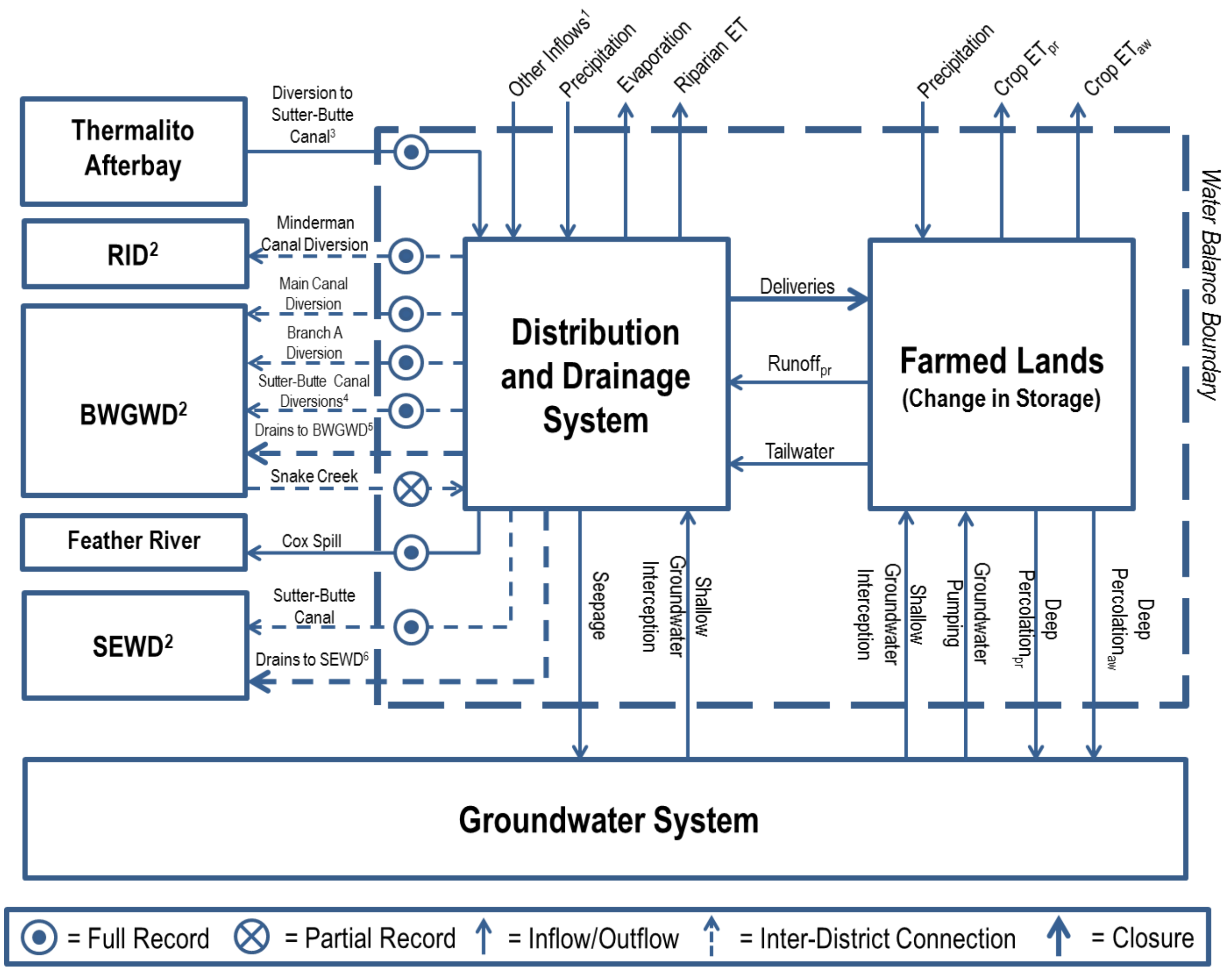
In general, flow paths are quantified on a monthly basis. For each accounting center, water volumes associated with certain flow paths are estimated independently based on measured data or calculated estimates, and the remaining flow is then calculated based on the principal of conservation of mass (Equation 4.1), which states that the difference between total inflows to and total outflows from an accounting center for a given period of time is equivalent to the change in stored water within that accounting center. For the distribution and drainage system, the change in storage is assumed to be zero on a monthly basis. For the farmed lands, the monthly change in storage varies, reflecting changes in the volume of water ponded in rice and managed wetlands areas as well as changes in soil moisture stored in the root zone. Over the course of a year the change in storage across all farmed lands is expected to be near zero.

$$Inflows - Outflows = Change\ in\ Storage\ (monthly\ time\ step) \qquad [4.1]$$

The flow path that is calculated using Equation 4.1 is referred to as the "closure term" because the mass balance equation is solved for or "closed" on the unknown quantity. The closure term is selected based on consideration of the availability of data or other information to support an independent estimate as well as the volume of water representing the flow path relative to the size of other flow paths. Generally speaking, the largest, most uncertain flow path is selected as the closure term.

Flow Path Estimation and Uncertainty

Individual flow paths were estimated based on direct measurements or based on calculations using measurements and other available data. As described previously, those flow paths not estimated independently were calculated as the closure term of each accounting center.



1. Other inflows include minor tributaries and drains.
2. RID is Richvale Irrigation District, BWGWD is Biggs-West Gridley Water District, and SEWD is Sutter Extension Water District.
3. Although the Sutter-Butte Canal is a Joint District facility, it is considered part of the BWD distribution system for the purposes of the water balance.
4. Sutter-Butte canal diversions includes the lateral 8 diversion.
5. Drains to BWGWD includes Hamilton Drain, Brooks Drain, and Meyers Drain, along with other minor sloughs and drains.
6. Drains to SEWD include Snake Creek, Morrison Slough (RD 2056), Live Oak Slough (RD 777), and other drains.

Figure 4.3. Water Balance Structure.

The analysis results for each flow path are reported with a high level of precision (nearest whole acre-foot) that implies a higher degree of accuracy than is actually justified. The estimated percent uncertainty (approximately equivalent to a 95 percent confidence interval) in each measured or calculated flow path has been estimated as part of the water balance analysis. Based on the relative magnitude of each flow path, the resulting uncertainty in each closure term can be estimated by assuming that errors in estimates are random (Clemmens and Burt 1997). Errors in estimates for individual flow paths may cancel each other out to some degree, but the combined error due to uncertainty in the various estimated flow paths is ultimately expressed in the closure term.

For the distribution and drainage system accounting center, aggregated surface outflows were calculated as the closure term, based on the assumption that the change in storage over time is zero. Total outflows were distributed across each individual outflow waterway (i.e., creeks and drains) based on available outflow measurements and estimated drainage areas tributary to each outflow location. Aggregated surface outflows were selected as the closure term because of the combination of the lack of available outflow data, generally large magnitude, and relative uncertainty of the flow path.

For the farmed lands accounting center, deliveries were calculated as the closure term. Deliveries were selected as the closure term because historical measurements were not readily available for the full period of analysis and they represent the largest inflow into the farmed lands accounting center. Deliveries calculated via closure include deliveries by BWD from its canals, laterals, and drains, as well as any district or private reuse of water or unaccounted groundwater pumping.

Table 4.4 lists each flow path included in the water balance indicating which accounting center(s) it belongs to; whether it is an inflow or an outflow; whether it was measured or calculated; the supporting information and assumptions used to determine it; the estimated uncertainty, expressed as a percent; and average values for the period of analysis. Results for both the full water year and for the primary irrigation season (April to September) are provided. As indicated, estimated uncertainties vary from 5% to 100% of the average volume for the irrigation season, with uncertainties generally being less for measured flow paths and greater for calculated flow paths.

The estimated uncertainty of each closure term is also shown. As indicated, the estimated uncertainty in aggregated surface outflows is 39% for the water year as a whole and 37% for the irrigation season. The estimated uncertainty in deliveries is 22% for the water year as a whole and 16% for the irrigation season. The uncertainty in deliveries decreases for the irrigation season due to the lack of precipitation from winter storms.

Table 4.4. Water Balance Flow Paths, Supporting Data, and Estimated Uncertainty.

Accounting Center	Flow Path Type	Flow Path	Source	Supporting Data	Water Year (Oct. - Sept.) Average Volume (af)	Water Year (Oct. - Sept.) Estimated Uncertainty	Irrigation Season (Apr. - Sept.) Average Volume (af)	Irrigation Season (Apr. - Sept.) Estimated Uncertainty
District Distribution and Drainage System	Inflow	Allotted Deliveries to Butte Water District[1]	Calculation	Joint Water Districts Board Measurement Data	106,597	20%	96,570	18%
		SEWD Conveyance Losses	Calculation	SEWD Allotted Deliveries x 0.176	26,354	10%	19,807	10%
		Other Inflows	Calculation	Estimated as zero	0	100%	0	100%
		Snake Creek	Calculation	Estimated in BWGWD Water Balance	20,967	23%	13,979	29%
		Precipitation	Calculation	Quality-controlled precipitation from CIMIS, estimated canal surface area	394	15%	78	15%
		Shallow Groundwater Interception	Calculation	Estimated as closure of regional water balance. Distributed within region based on area, drain miles, and average depth to groundwater.	4,366	70%	5,068	70%
		Runoff of Precipitation	Calculation	IDC analysis, NRCS soils characteristics, CIMIS precipitation data	11,679	25%	1,449	25%
		Tailwater	Calculation	Estimated as 20% of Deliveries	22,339	30%	19,914	30%
	Outflow	**Deliveries (to Farmed Lands)**	**Closure (Farmed Lands)**	**Closure term of Farmed Lands water balance**	**75,765**	**22%**	**67,453**	**16%**
		Evaporation	Calculation	CIMIS reference ET, estimated evaporation coefficient, estimated wetted surface area	944	15%	840	15%
		Riparian ET	Calculation	CIMIS reference ET, estimated crop coefficient based on 2009 SEBAL analysis, estimated riparian area	167	15%	138	15%
		Seepage	Calculation	NRCS soils data, published seepage rates by soil type, estimated wetted area, estimated wetted duration	34,860	35%	24,230	35%
		Drains to BWGWD	**Closure (District Distribution and Drainage System)**	**Difference between total inflows and measured/estimated outflows for Distribution and Drainage System accounting center, distributed according to drainage area and available data, BWGWD Operational Data, California Water Data Library Sites A00910 and A02980**	**24,287**	**39%**	**19,262**	**37%**
		Other Drains			**56,671**		**44,944**	
Farmed Lands	Inflow	Precipitation	Calculation	Quality-controlled precipitation from CIMIS station, reported cropped area	53,095	15%	10,497	15%
		Deliveries	**Closure (Farmed Lands)**	**Difference between measured/estimated inflows and total outflows for Farmed Lands accounting center, including estimated Tailwater as percentage of Deliveries**	**75,765**	**22%**	**67,453**	**16%**
		Shallow Groundwater Interception	Calculation	Estimated as closure of regional water balance. Distributed within region based on area, drain miles, and average depth to groundwater.	2,910	70%	3,378	70%
		Groundwater Pumping	Calculation	Estimated pumping based on estimated groundwater acres and associated applied water estimated from IDC.	22,980	25%	19,275	25%
	Outflow	Tailwater	Calculation	Estimated as 20% of Deliveries	22,339	30%	19,914	30%
		Crop ET of Applied Water	Calculation	CIMIS reference ET; estimated crop coefficients based on SEBAL 2009 analysis; crop acreages from WCWD records, DWR land use surveys, and agricultural commissioner crop reports; Integrated Water Flow Model Demand Calculator (IDC) analysis to divide total ET into applied water and precipitation components	58,176	10%	48,063	10%
		Crop ET of Precipitation	Calculation		27,647	10%	17,836	10%
		Runoff of Precipitation	Calculation	IDC analysis, NRCS soils characteristics, CIMIS precipitation data	11,679	25%	1,449	25%
		Deep Percolation of Applied Water	Calculation	IDC analysis, NRCS soils characteristics, CIMIS precipitation data, Integrated Water Flow Model Demand Calculator (IDC) analysis to divide total deep perc. into applied water and precipitation components	21,342	35%	11,592	35%
		Deep Percolation of Precipitation	Calculation		12,810	35%	3,657	35%
	Change in Storage		Calculation	IDC Analysis	757	50%	-1,910	50%

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4.7.3 Water Use

The district supplies agricultural irrigation water and also provides water for environmental use to provide wildlife habitat within and outside its service area. These water uses are described in greater detail in the remainder of this section.

Agricultural

Agricultural irrigation is by far the dominant water use in the BWD service area. Between 1999 and 2019, there were an average of approximately 15,000 cropped acres supplied water by BWD, with an average of 1,700 additional acres of fallow or idle land. BWD does not provide surface water for the irrigation of all crops within its service area. A portion of the agricultural lands within BWD's boundaries rely exclusively on groundwater or incidental reuse of tailwater for irrigation. These lands represent approximately 10,000 acres and are included in the water balance for purposes of analysis but are not supplied water by BWD.

Table 4.5 and Figure 4.4 present estimated BWD crop acreages for the period of analysis. As indicated, the main crops in the district are permanent orchard crops, primarily walnuts and prunes, which were grown on an average of 7,700 acres between 1999 and 2019, representing 52% of the total cropped area, or 46% of the irrigable area. Between 1999 and 2019, rice was grown on an average of 5,900 acres or 40% of total cropped area. A variety of other crops including field and truck crops, pasture and hay are grown on the remaining land, which accounts for an average of 1,200 acres or 8% of total cropped area. The acreage of these various other crops has been decreasing over time. The increase in idle acres in 2003, 2008, 2010, 2012, 2014, and 2018 resulted from crop idling-based water transfers.

Crop evapotranspiration (ET) was estimated using a crop coefficient approach, whereby estimated crop- and time-specific water use coefficients were multiplied by reference ET (ET_o) to calculate the total consumptive use of water for the farmed lands over time. Crop coefficients specific to the Sacramento Valley were developed based on actual ET estimates from a remote sensing analysis using the Surface Energy Balance Algorithm for Land (SEBAL). The analysis used ground and satellite data to compute actual ET from March to September for individual 30-meter satellite pixels within Glenn and Colusa counties in 2009. Spatially distributed cropping data from DWR land use surveys for Glenn and Colusa counties for 2009 were combined with quality-controlled reference evapotranspiration (ET_o) from CIMIS to calculate crop coefficients representing actual ET over the course of the growing season[6]. A map showing March to September ET estimates for BWD from SEBAL for 2009 is provided in Figure 4.5.

[6] Ideally, the crop coefficient analysis would have included portions of Butte, Sutter, and Yuba counties within the Feather River region; however, DWR land use surveys were not available for 2009 for these counties. Crop coefficients developed for Glenn and Colusa counties are considered reasonably representative for the region as a whole.

Table 4.5. Crop and Idle Acres, 1999-2019.

Year	Crop Acreage by Type					
	Rice	Orchards	Other	Idle	Total Cropped	Total with Idle
1999	6,207	9,795	1,435	416	17,437	17,853
2000	6,280	9,280	1,494	439	17,054	17,493
2001	6,226	9,151	1,406	691	16,783	17,474
2002	6,896	8,388	1,430	700	16,714	17,414
2003	4,390	8,081	1,331	3,950	13,802	17,752
2004	7,806	8,188	1,220	421	17,214	17,635
2005	7,694	8,115	1,206	614	17,014	17,628
2006	7,620	7,966	1,196	630	16,782	17,412
2007	7,892	7,820	1,452	555	17,163	17,718
2008	3,944	8,205	1,730	3,636	13,878	17,514
2009	7,924	8,093	1,560	460	17,576	18,036
2010	4,514	8,108	1,086	3,783	13,709	17,492
2011	7,961	7,914	1,127	435	17,002	17,437
2012	4,982	7,376	1,185	3,961	13,543	17,504
2013	8,052	7,117	1,198	737	16,367	17,104
2014	4,971	7,359	1,232	3,830	13,562	17,392
2015	3,473	7,195	1,097	1,007	11,765	12,772
2016	6,405	6,063	773	491	13,241	13,732
2017	4,134	5,956	741	3,685	10,831	14,516
2018	1,575	5,701	760	5,039	8,036	13,075
2019	5,843	5,757	629	426	12,229	12,655
Average	5,942	7,697	1,204	1,710	14,843	16,553

Notes:
1.) Rice, Orchards, and Other are from estimates of Rice, General, and Other, respectively, from JB reports

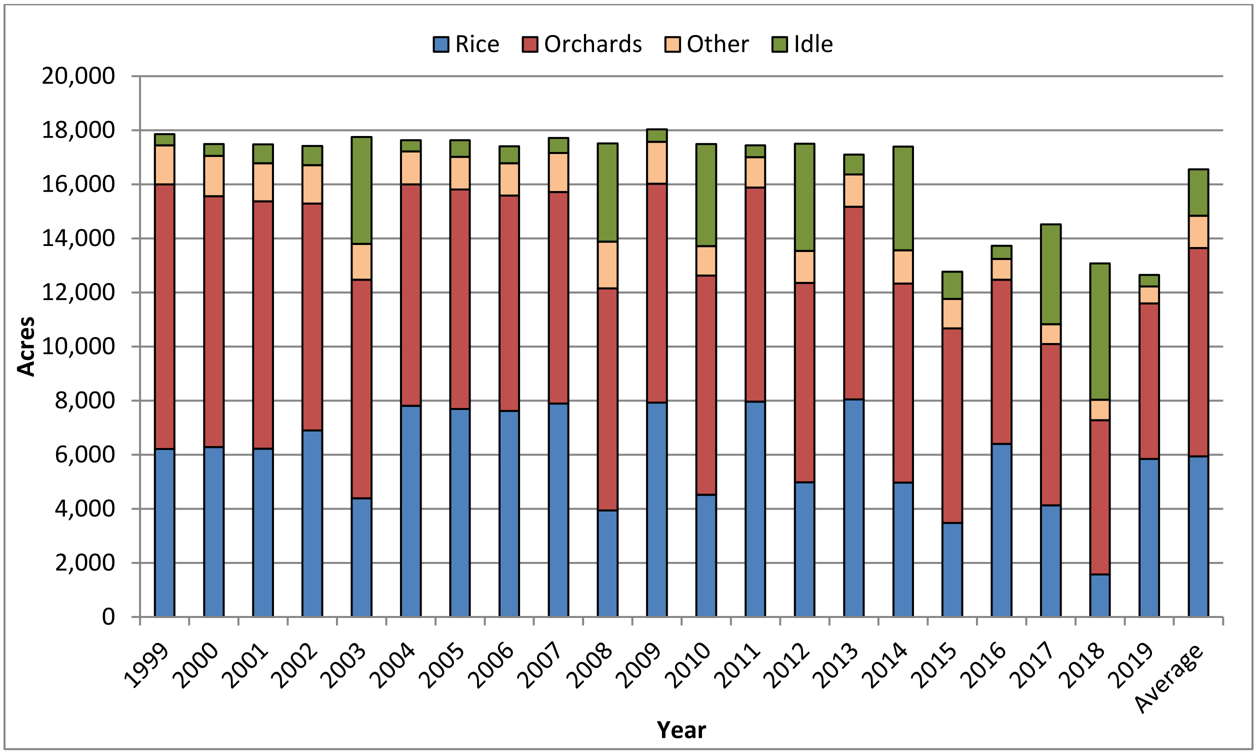

Figure 4.4. Crop and Idle Acres, 1999-2019[7].

A root zone water balance simulation was developed for each crop using the Integrated Water Flow Model (IWFM) Demand Calculator (IDC) Version 4.0 developed by DWR to estimate the portions of total ET derived from applied water (ET_{aw}) and from precipitation (ET_{pr}). ET values for each crop, expressed in units of acre-feet per acre were multiplied by the corresponding acreage in each year to compute total water volumes consumed for agricultural purposes.

For rice, the IDC model simulates ponding during the growing season and during the decomposition period in the fall and winter. As a result, precipitation occurring when ponds are full runs off of the fields and is not available to contribute to crop ET. Precipitation stored in the soil during the winter is available for extraction. For non-ponded crops, runoff and infiltration of precipitation are modeled for individual precipitation events. Precipitation entering the soil may be stored and available to support crop ET, or it may leave the root zone as deep percolation. One result of the differences in irrigation and cultural practices between rice and non-ponded crops is that ET_{pr} is significantly less for rice. Additional detail describing rice water management is provided in Volume I, Section 2.

[7] Total acres vary somewhat from year to year reflecting estimated changes in total irrigable acres resulting from rural development and changes in areas of native vegetation.

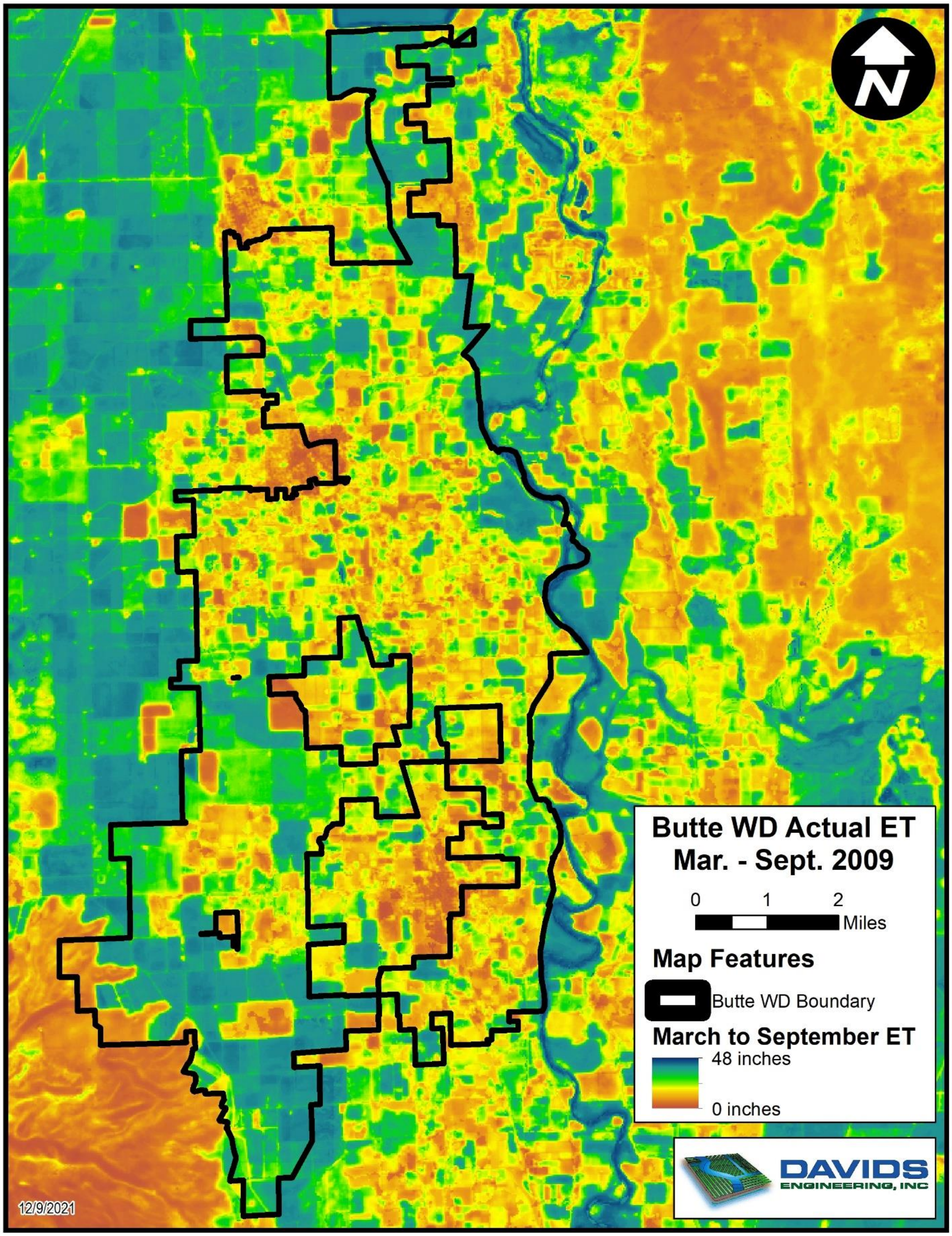

Figure 4.5. March to September 2009 SEBAL Actual ET.

Starting in 2015, water budget results presented in this AWMP are based on the Butte Basin Groundwater Model (BBGM) developed to support recent, local water management activities, including SGMA. The BBGM was developed using the latest available datasets including land use, precipitation, and actual evapotranspiration. Results from the BBGM for each land use category, expressed in units of acre-feet per acre, were multiplied by the corresponding acreage within the District's service area and incorporated into the District's water balance. Further information on the BBGM is available through Butte County's Department of Water and Resource Conservation.

The monthly consumptive use of water in BWD ranges from approximately 1 inch of total ET in December and January to nearly 6 inches in June and July. A majority of ET is derived from applied water, and ET_{aw} ranges from approximately 0.7 inches in December and January to approximately 4.6 inches in July for the irrigable area. The average monthly consumptive use of water is presented in Figure 4.6.

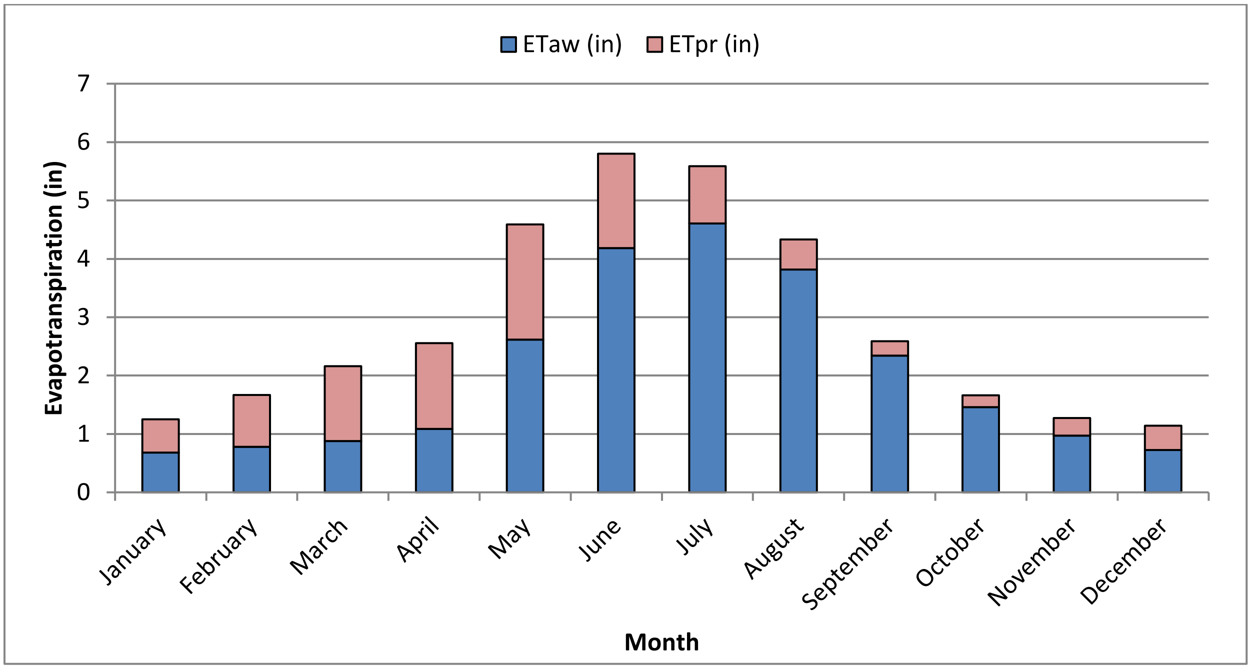

Figure 4.6. Average Monthly Consumptive Use of Water.

The annual consumptive use of water by crops in BWD is approximately 50 inches of total crop ET for rice, approximately 36 inches for permanent orchard crops and approximately 34 inches for various other crops, as shown in Table 4.6. ET_{aw} ranges from approximately 23 inches to 43 inches. For rice, approximately 43 inches of the 50 inches of total ET are derived from applied irrigation water. On average, approximately 24 inches of 35 inches of total ET are derived from applied irrigation water district wide.

ET_c and ET_{aw} vary from year to year due to differences in atmospheric water demand (ET_o) and differences in the timing and amount of precipitation available to support crop growth and offset crop irrigation requirements. Total annual ET varied between approximately 73,000 af and 98,000 af during the 1999 to 2019 period, with an average annual volume of 86,000 af. On average, approximately 58,000 af of ET were derived from applied irrigation water (68% of total ET) and 28,000 af of ET were derived from precipitation (32% of total ET).

Table 4.6. Average Acreages and Annual Evapotranspiration Rates by Crop.

Crop	Average Acres	Average Evapotranspiration (in)		
		ET_c	ET_{aw}	ET_{pr}
Rice	5,942	50.0	42.6	7.4
Orchard	7,697	36.2	24.2	12.0
Other	1,204	33.9	23.3	10.6
Idle	1,710	10.4	0.4	10.0
Totals	16,553	34.6	24.1	10.5

ET_c and ET_{aw} vary from year to year due to differences in atmospheric water demand (ET_o) and differences in the timing and amount of precipitation available to support crop growth and offset crop irrigation requirements. Total annual ET varied between approximately 73,000 af and 98,000 af during the 1999 to 2019 period, with an average annual volume of 86,000 af. On average, approximately 58,000 af of ET were derived from applied irrigation water (68% of total ET) and 28,000 af of ET were derived from precipitation (32% of total ET).

Other uses of applied irrigation water include winter flooding for habitat and rice straw decomposition (discussed in the following section), leaching of salts, and frost protection for orchard crops. Due to the low salinity of groundwater in BWD and in surface water diverted from the Feather River, the required leaching fraction is small for the crops grown in the district. Additionally, water applied for frost protection is typically applied outside of the irrigation season and is a minor use. Volumes for leaching of salts and frost protection are relatively small and have not been quantified at this time; however, to the extent that they are provided for through water delivery by BWD, they are included and accounted for in the overall delivery volumes in the water balance.

Environmental and Recreational

Approximately 67 percent or 4,000 acres of the rice fields in BWD are typically estimated to be flooded in the winter following harvest to aid in rice straw decomposition and to create winter habitat for migratory waterfowl and shorebirds along the Pacific Flyway. Use of water during the winter for rice decomposition and waterfowl habitat increased substantially between 1992 and 2001, largely driven by the phasing out of burning of rice straw as a result of the Connelly-Areias-Chandler Rice Straw Burning Reduction Act of 1991. Winter flooded acres have remained relatively steady since around 2000.

Diversions and estimated applied water for rice straw decomposition and wildlife habitat within BWD are provided in Table 4.7. These estimates are based on measured diversions and estimated applied water (delivery term from water balance analysis) for the October – March period. Some water delivered during October is for irrigation of orchard crops. Diversions are zero between February and March, although private reuse of available water may occur and is included in the estimated applied water.

Table 4.7. Estimated Winter Diversions and Applied Water for Managed Wetlands and Rice Straw Decomposition.

Water Year	Winter Net Diversions (af)	Applied Water (af)[1]
1999	1,808	4,466
2000	11,344	9,328
2001	3,490	6,384
2002	10,534	6,135
2003	10,080	5,902
2004	7,578	4,559
2005	3,572	4,624
2006	9,624	5,776
2007	13,412	15,674
2008	6,120	13,938
2009	9,016	4,972
2010	15,670	6,257
2011	12,392	5,374
2012	14,030	18,460
2013	11,064	14,759
2014	22,864	16,940
2015	10,292	15,250
2016	6,252	150
2017	10,338	4,444
2018	11,540	9,243
2019	9,546	1,933
Average	9,191	7,989

1. Estimated based on water balance analysis. Includes deliveries plus reuse.

The water supplied during the winter period provides critical habitat to support migratory waterfowl and shorebirds while also creating recreational opportunities. Aside from this, there are no recreational water uses within the district.

In addition to use of water within the district to provide winter habitat, surface outflows from BWD flow to BWGWD and SEWD where they can enter Gray Lodge Wildlife Area, the Butte Sink, and ultimately the Sutter Bypass, providing important flows to support migration of salmon and steelhead and other downstream uses of water for wildlife habitat, such as diversions by Sutter National Wildlife Refuge to support seasonal wetlands. Outflows from the BWD service area are discussed in greater detail in the drainage and water balance sections.

Municipal and Industrial

BWD does not provide any municipal or industrial water at this time. The cities of Gridley and Live Oak are encompassed by the District's boundary, and the city of Biggs is adjacent to the District.

Groundwater Recharge

Groundwater recharge that occurs within the district's service area consists of seepage from canals and private ditches, as well as deep percolation of precipitation and applied irrigation water. Distributed recharge through seepage and deep percolation provides a means to replenish the groundwater system to the benefit of BWD water users, the communities of Biggs, Gridley, and Live Oak, other individuals within BWD, and surrounding areas overlying the Butte and Sutter groundwater subbasins.

Estimates of recharge were developed as part of the water balance analysis. Specifically, canal and drain seepage estimates were calculated based on estimated soil hydraulic characteristics along with estimated canal and drain wetted perimeters, overall lengths, and wetting frequency. Deep percolation of applied irrigation water and precipitation were calculated based on estimated applied irrigation water amounts over time as influenced by ET_o, precipitation, crop, and soil type, and simulated by the IDC model described previously.

Estimated annual seepage and deep percolation volumes for water years 1999 to 2019 are provided in Table 4.8, along with total recharge expressed as a volume and as a depth of water for each year.

Table 4.8. Total Groundwater Recharge, 1999-2019.

Water Year	Canal Seepage (af)	Deep Percolation of Applied Water (af)	Deep Percolation of Precipitation (af)	Total Recharge	
				af	af/ac
1999	35,355	21,627	12,300	69,282	2.6
2000	35,355	25,898	15,731	76,985	2.9
2001	35,355	21,288	10,376	67,019	2.7
2002	35,355	25,218	14,523	75,096	3.0
2003	35,355	19,531	14,227	69,114	3.2
2004	35,355	24,017	15,107	74,480	3.0
2005	35,355	21,564	14,613	71,532	2.8
2006	31,889	23,994	22,441	78,324	3.2
2007	35,355	22,120	4,815	62,290	2.5
2008	35,355	21,668	9,389	66,412	3.0
2009	35,355	21,957	6,873	64,185	2.6
2010	31,889	20,297	13,208	65,394	2.9
2011	35,355	22,258	21,244	78,857	3.1
2012	31,889	20,418	10,077	62,383	2.8
2013	35,355	23,195	6,821	65,371	2.5
2014	35,355	20,320	2,602	58,277	2.7
2015	35,355	18,773	7,760	61,888	2.6
2016	35,355	18,985	12,281	66,620	2.6
2017	35,355	21,101	25,492	81,947	3.6
2018	35,355	13,026	7,575	55,956	2.6
2019	35,355	20,933	21,565	77,854	3.0
Average	34,860	21,342	12,810	69,013	2.8

Total recharge between 1999 and 2019 ranged from approximately 56,000 af to 82,000 af per year, or from 2.5 af to 3.6 af per acre per year. On average between 1999 and 2019, total recharge was estimated to be approximately 69,000 af per year (2.8 af/ac-year), with approximately 50% of recharge originating from canal seepage, 31% of from deep percolation of applied water, and 19% from deep percolation of precipitation.

Groundwater level monitoring data and field observations suggest that the shallow groundwater system and regional aquifer may be coupled within portions of BWD's service area at certain times and that an unsaturated aquifer zone may thus not be present to receive recharge. Depth to water in residential and irrigation wells is commonly less than ten feet, and drains flow in some areas even when irrigation is not occurring. These conditions likely result from limited groundwater pumping in the area historically along with sustained use of surface water for irrigation over past decades. As a result, it is likely that a substantial portion of the water percolating into the soil from ponded fields and seeping from canals may be unable to flow downward and rather flows horizontally to where it is intercepted by non-ponded vegetation or by drains, providing base flow. Shallow groundwater interception is shown conceptually in Figure 4.7 and discussed in a regional context in Volume I of this AWMP.

Even in areas where an unsaturated zone is present, water infiltrating into the soil in ponded fields may encounter impermeable layers caused by plow pan or natural soil features and flow laterally to adjacent lands or provide base flow for drains. Additional information is needed to distinguish shallow groundwater interception in areas where the shallow and regional groundwater systems are coupled from areas with perched shallow groundwater.

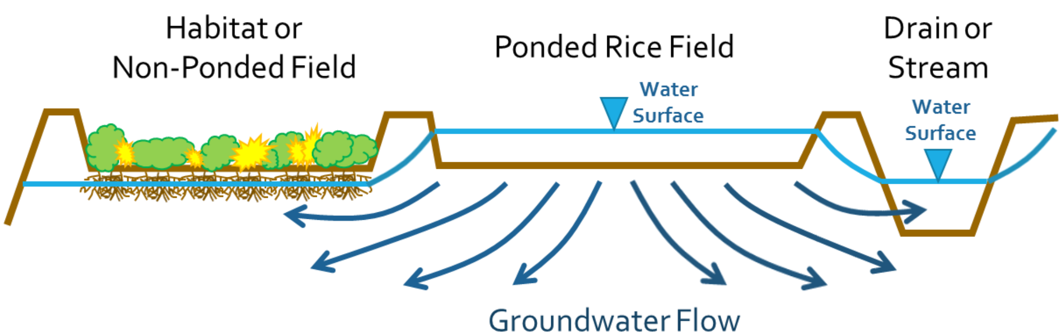

Figure 4.7. Conceptualization of Shallow Groundwater Interception in Rice Growing Areas.

Groundwater recharge net of well pumping and shallow groundwater interception was calculated by subtracting estimated pumping volumes from total recharge volumes. Shallow groundwater interception occurs when drains, creeks, or other waterways intercept or "gain" water from the shallow groundwater system, which may be perched or connected to the regional aquifer. Additionally, shallow groundwater can be intercepted and consumed by natural or other non-ponded vegetation. Net annual recharge estimates for 1999 to 2019 are provided in Table 4.9.

Net recharge varied from approximately 16,000 af to 59,000 af per year between 1999 and 2019, or 0.6 af to 2.2 af per acre per year. On average between 1999 and 2019, net recharge was estimated to be approximately 39,000 af per year (1.5 af/ac-year).

Table 4.9. Net Groundwater Recharge, 1999-2019.

Year	Total Recharge (af)	Groundwater Pumping (af)	Shallow Groundwater Interception (af)	Net Recharge	
				af	af/ac
1999	69,282	16,360	7,276	45,645	1.7
2000	76,985	17,657	7,276	52,052	2.0
2001	67,019	19,058	7,276	40,685	1.5
2002	75,096	19,820	7,276	47,999	1.8
2003	69,114	16,437	7,276	45,400	1.7
2004	74,480	20,944	7,276	46,260	1.8
2005	71,532	17,702	7,276	46,554	1.7
2006	78,324	18,228	7,276	52,821	2.0
2007	62,290	26,747	7,276	28,267	1.1
2008	66,412	24,615	7,276	34,521	1.3
2009	64,185	28,892	7,276	28,016	1.1
2010	65,394	24,453	7,276	33,665	1.3
2011	78,857	18,800	7,276	52,780	2.0
2012	62,383	25,095	7,276	30,012	1.1
2013	65,371	36,697	7,276	21,398	0.8
2014	58,277	35,030	7,276	15,971	0.6
2015	61,888	38,519	7,276	16,092	0.6
2016	66,620	24,714	7,276	34,630	1.3
2017	81,947	15,373	7,276	59,298	2.2
2018	55,956	20,123	7,276	28,557	1.0
2019	77,854	17,313	7,276	53,264	2.0
Average	69,013	22,980	7,276	38,757	1.5

Transfers and Exchanges

The district participated in ten voluntary water transfers between 1999 and 2019 with parties outside of the region. Surface water was made available for transfer through six crop idling-based transfers and four groundwater substitution transfers. For crop idling water transfers, participating landowners idled land within the district and transferred the surface water that would have been applied and consumed in lieu of the project. The quantity of water transferred was based on DWR estimates of the annual evapotranspiration of applied water for rice (3.3 af/ac). The amount of water transferred from crop idling is estimated in Table 4.10.

Table 4.10. Crop Idling Water Transfer Volumes, 1999-2019.

Year	Idle Acreage	Transfer Volume (af)
2003	3,441	11,355
2008	3,032	10,006
2010	3,116	10,281
2012	3,309	10,919
2014	3,267	10,780
2018	4,900	16,170

Pumping amounts from groundwater substitution in 2009, 2010, 2013, and 2014 were 4,102 af, 3,846 af, 3,838 af, and 4,708 af, respectively. Pumping amounts were decreased by 12% to determine the transferable amount based on estimated stream depletion.

Additionally, BWD and SEWD have historically provided water to other of the Joint Districts through local water transfers. The primary recipients of within-region transfers have been BWGWD and RID. Water was provided in seven of the nine years between 2006 and 2014, ranging from 3,000 af to 26,000 af annually with an average transfer amount of 14,000 af. Historically, BWD has provided approximately 55% of the water transferred, with SEWD providing the remaining 45%.

Other Water Uses

Other incidental uses of water within BWD may include watering of roads for dust abatement or agricultural spraying. The volume of water used for such purposes is very small relative to other uses and, thus, not itemized, but is accounted for in the water budget as part of the volume of farm deliveries.

4.7.4 Drainage

Surface Outflows

Surface drains within BWD convey runoff of precipitation, surface inflows from upgradient lands, runoff of irrigation water (tailwater), and provide shallow groundwater relief by capturing canal seepage and intercepting shallow groundwater. Surface drains are also an important source of water for crop season irrigation and winter flooding. All water leaving the district as surface outflows is available for reuse by downstream water users and the environment. Annual surface outflows are summarized in Table 4.11.

Water year boundary outflows ranged from approximately 44,000 af to 106,000 af between 1999 and 2019 with an average of 81,000 af. Based on estimated outflow flow rates and estimated tributary areas above each outflow location, total boundary outflows been divided among the two primary outflow locations. It is estimated that approximately 30% of total outflows flow to BWGWD with the remaining 70% of outflows flowing to SEWD.

Tailwater

The private farmed lands water balance includes an estimate of the volume of tailwater entering the distribution and drainage system that is available for reuse. A portion of this volume is reused internally by the district and individual water users and is accounted for in the estimated deliveries; the remainder is available for reuse by downgradient water users in BWGWD and SEWD. Table 4.12 presents the estimated annual tailwater volumes between water years 1999 and 2019.

Tailwater entering the distribution and drainage system between 1999 and 2019 ranged from approximately 10,000 af to 29,000 af per year. The overall average tailwater for this period was 22,000 af per year.

Table 4.11. Estimated Surface Outflow Volumes, 1999-2019.

Water Year	Drains to BWGWD (af)	Drains to SEWD (af)	Total Boundary Outflows (af)
1999	17,430	40,671	58,101
2000	21,661	50,541	72,202
2001	20,529	47,902	68,432
2002	29,120	67,948	97,068
2003	31,196	72,791	103,987
2004	24,538	57,256	81,794
2005	20,176	47,078	67,254
2006	27,136	63,318	90,454
2007	22,884	53,395	76,279
2008	22,930	53,503	76,432
2009	25,765	60,119	85,884
2010	27,522	64,218	91,741
2011	28,291	66,013	94,304
2012	21,272	49,636	70,908
2013	21,483	50,126	71,608
2014	21,168	49,393	70,561
2015	13,109	30,587	43,695
2016	21,390	49,911	71,301
2017	31,363	73,180	104,543
2018	29,342	68,465	97,808
2019	31,728	74,031	105,759
Average	24,287	56,671	80,958

Table 4.12. Estimated Tailwater Volumes, 1999-2019.

Water Year	Tailwater (af)
1999	28,112
2000	29,112
2001	26,449
2002	27,902
2003	19,616
2004	26,619
2005	22,621
2006	23,648
2007	29,143
2008	24,490
2009	23,145
2010	18,656
2011	19,334
2012	22,251
2013	24,646
2014	22,640
2015	9,758
2016	20,091
2017	16,371
2018	14,507
2019	20,003
Average	22,339

Reuse

BWD can recover water into the distribution system at two pump stations; however, they are typically not used because the water is recovered and reused downstream in drains by BWD customers. It is estimated that approximately 30% of annual applied surface water within BWD is through reuse, or approximately 25,000 af annually. Reuse by water users in BWD reduces diversion requirements from the afterbay and results in district-scale water use efficiencies that would otherwise not be attained. Implications of reuse at the district and regional scales are further discussed in the following section.

4.7.5 Water Accounting (Summary of Water Balance Results)

The BWD water balance structure was shown previously in Figure 4.3. The water balance was prepared for the distribution and drainage system and for farmed lands. Additionally, the water balance can be summarized for the BWD service area as a whole ("Water Balance Boundary" shown in Figure 4.3). An accounting center representing the groundwater system is also included in Figure 4.3 to account for exchanges between the root zone and the underlying groundwater system; however, a complete balance for the underlying aquifer has not been developed because not all inflows and outflows into the groundwater system (such as horizontal boundary flows) have been estimated.

As depicted in Figure 4.3 and discussed previously, interconnection exists between the accounting centers due to recapture and reuse of water by both the BWD distribution system and directly by water users. Specifically, surface runoff of applied water (tailwater) flows back into the distribution and drainage system. Within the drainage system, reuse of water originating as tailwater, operational spillage, or from other sources is practiced by individual water users. This water recovery and reuse results in higher levels of aggregate performance than would otherwise occur.

The water balance results are presented on a water year basis for 1999 through 2014. Underlying the annual time step is a more detailed water balance in which all flow paths are estimated on a monthly basis.

District-Wide and Individual Accounting Center Water Balance Results

A district-wide water balance combining individual inflows and outflows into general categories is shown in Figure 4.8 for the water year and for the April to September irrigation season. Average volumes are presented for each inflow and outflow category, as well as average volumes expressed in acre-feet per acre. Average monthly inflows to and outflows from BWD are further summarized in Figures 4.9 and 4.10, respectively.

Detailed annual water balance results for the distribution and drainage system are summarized in Table 4.13. Detailed annual water balance results for the farmed lands are summarized in Table 4.14. In each table, performance indicators discussed in the following section are provided.

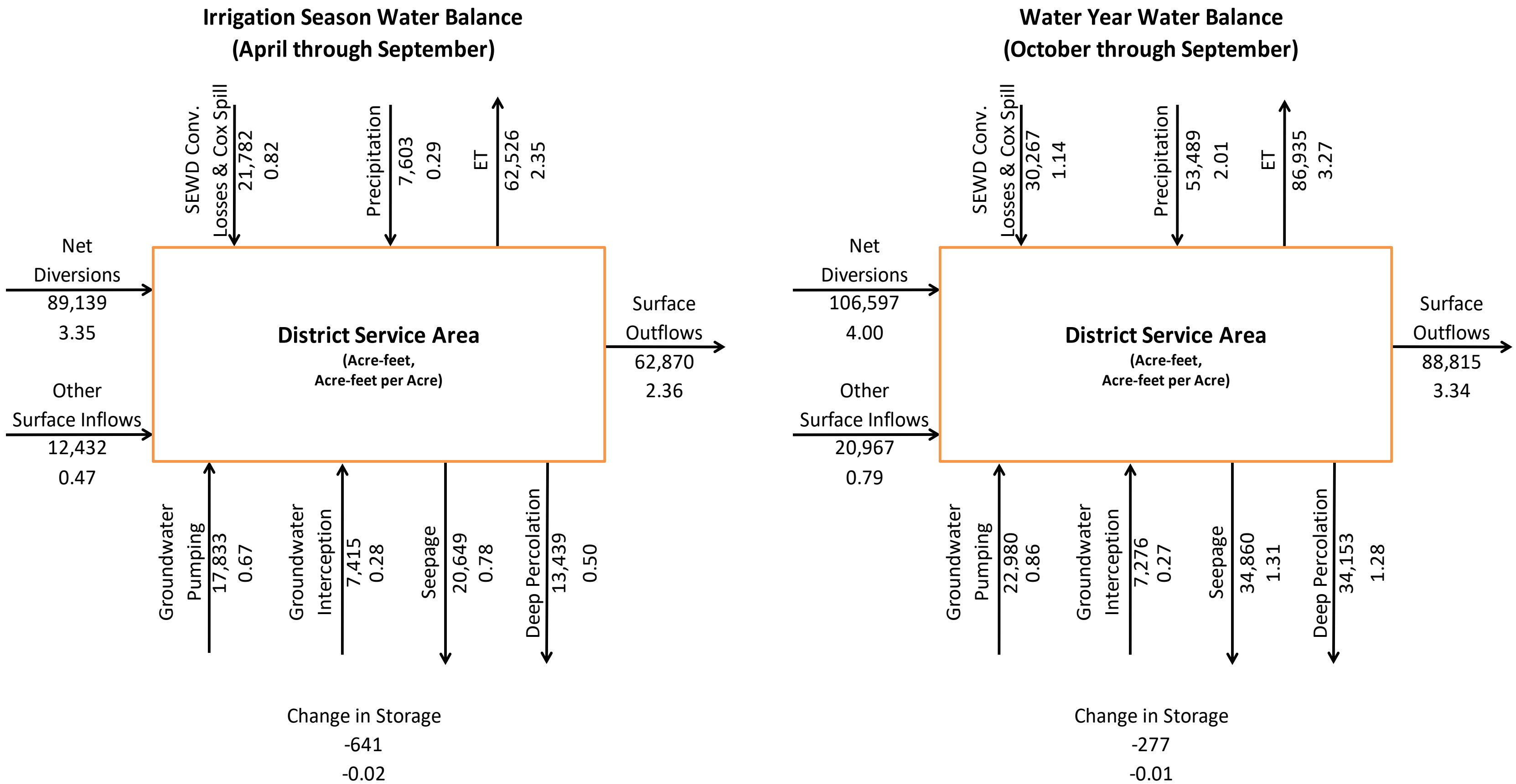

Figure 4.8. District Water Balance 1999-2019.

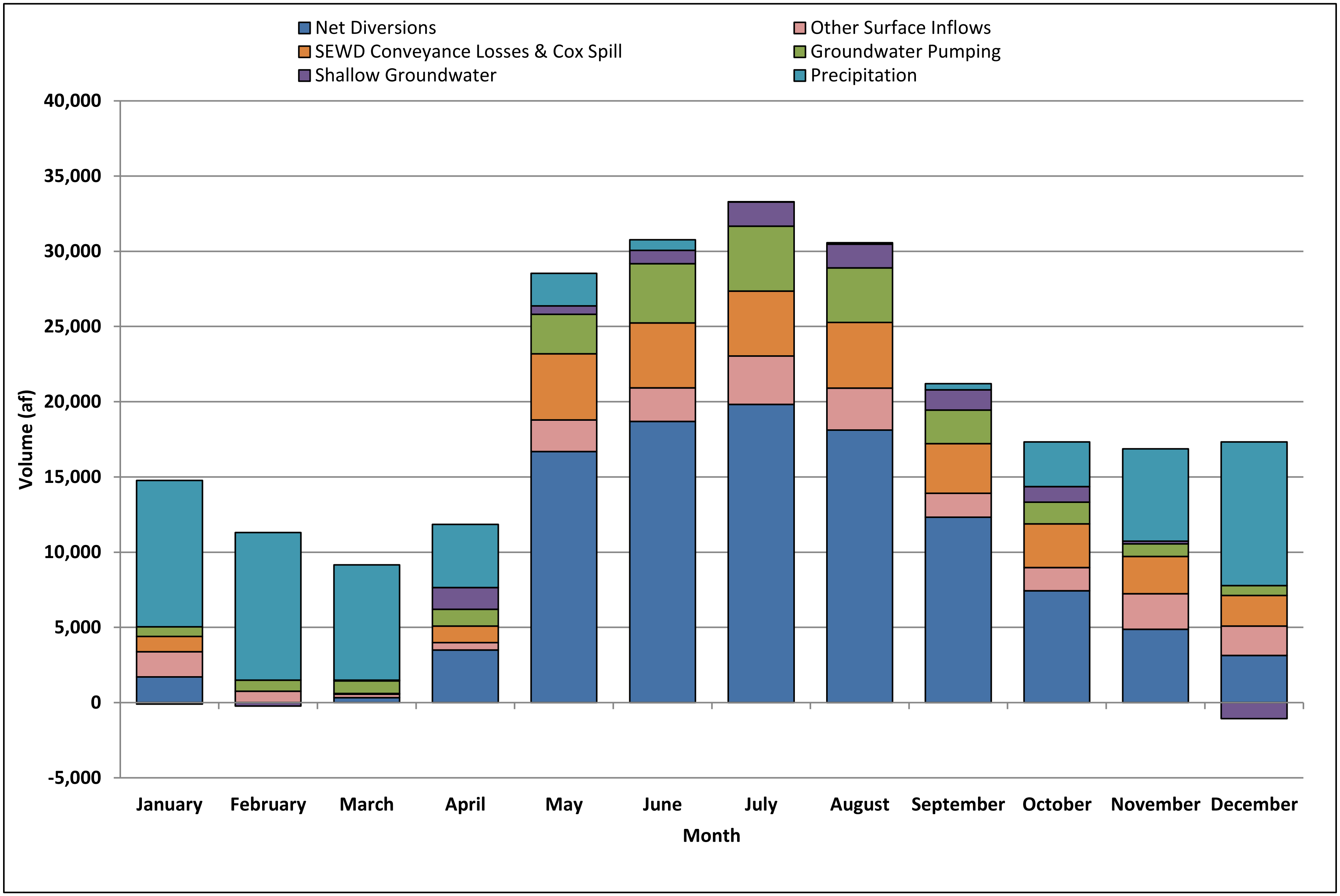

Figure 4.9. Average Monthly Inflows, 1999-2019.

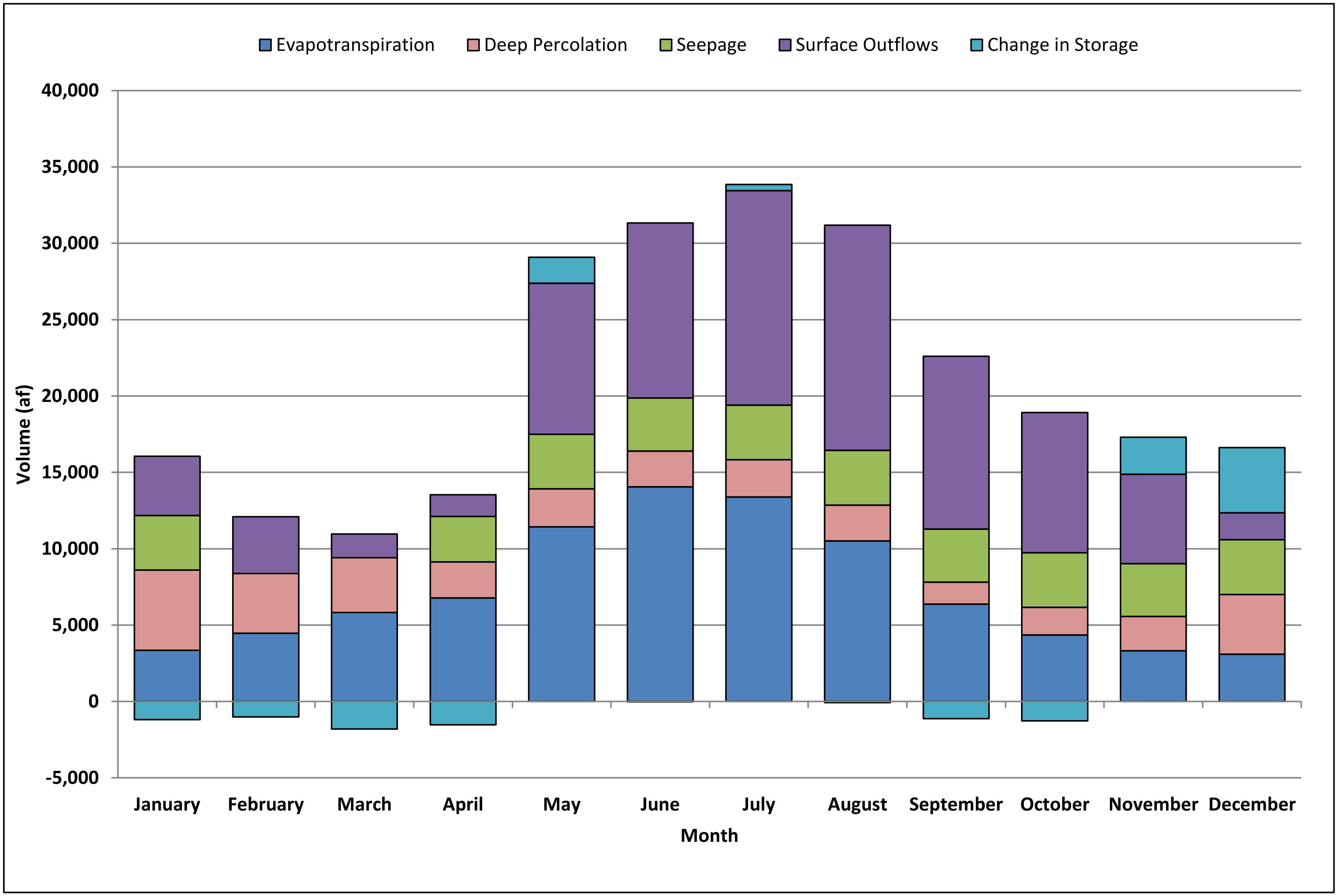

Figure 4.10. Average Monthly Outflows, 1999-2019.

Table 4.13. Distribution and Drainage System Annual Water Balance Results, 1999-2019.

Water Year	Inflows (af)						Outflows (af)						Performance Indicators	
	Net Deliveries to Butte Water District Distribution System	SEWD Estimated Conveyance Losses	Snake Creek	Precipitation	Shallow Groundwater Interception	Runoff of Precipitation	Tailwater	Deliveries	Evaporation	Riparian ET	Seepage	Boundary Outflows	Delivery Fraction	Water Management Fraction
1999	105,068	25,957	18,692	330	4,366	5,741	28,112	93,707	938	152	35,355	58,101	0.89	0.994
2000	111,670	27,205	20,819	433	4,366	12,158	29,112	97,041	994	156	35,355	72,202	0.87	0.994
2001	108,944	27,880	18,255	338	4,366	6,908	26,449	88,163	1,015	161	35,355	68,432	0.81	0.994
2002	133,408	28,669	20,610	401	4,366	11,256	27,902	93,008	1,005	159	35,355	97,068	0.70	0.995
2003	117,288	26,694	22,347	472	4,366	15,071	19,616	65,386	964	154	35,355	103,987	0.56	0.995
2004	104,556	29,881	29,147	386	4,366	12,078	26,619	88,730	994	160	35,355	81,794	0.85	0.994
2005	87,121	29,439	23,489	465	4,366	11,575	22,621	75,402	901	146	35,355	67,254	0.87	0.994
2006	96,958	27,179	29,727	563	4,366	19,756	23,648	78,828	871	145	31,889	90,454	0.81	0.995
2007	117,606	32,130	22,213	242	4,366	4,252	29,143	97,143	989	170	35,355	76,279	0.83	0.994
2008	107,532	27,805	21,669	307	4,366	8,411	24,490	81,634	976	168	35,355	76,432	0.76	0.994
2009	119,204	26,611	18,706	302	4,366	7,133	23,145	77,150	907	157	35,355	85,884	0.65	0.995
2010	102,506	27,513	22,283	423	4,366	11,056	18,656	62,188	828	145	31,889	91,741	0.61	0.995
2011	99,764	26,732	28,317	575	4,366	15,970	19,334	64,447	800	139	35,355	94,304	0.65	0.995
2012	93,098	27,197	23,296	341	4,366	7,455	22,251	74,170	868	156	31,889	70,908	0.80	0.994
2013	109,723	27,058	19,617	254	4,366	4,640	24,646	82,153	1,013	163	35,355	71,608	0.75	0.994
2014	114,966	25,087	13,856	149	4,366	1,526	22,145	73,817	1,030	165	35,355	70,561	0.64	0.987
2015	94,021	14,219	9,472	252	4,366	8,019	9,758	59,933	962	162	35,355	43,695	0.64	0.992
2016	99,775	19,642	16,602	407	4,366	13,806	20,091	66,920	944	169	35,355	71,301	0.67	0.994
2017	100,568	24,057	20,396	672	4,366	29,115	16,371	54,571	916	158	35,355	104,543	0.54	0.995
2018	105,733	26,439	20,396	332	4,366	10,886	14,507	48,357	970	168	35,355	97,808	0.46	0.994
2019	109,031	26,032	20,396	633	4,366	28,443	20,003	66,675	949	164	35,355	105,759	0.61	0.995
Minimum	87,121	14,219	9,472	149	4,366	1,526	9,758	48,357	800	139	31,889	43,695	0.46	0.987
Maximum	133,408	32,130	29,727	672	4,366	29,115	29,143	97,143	1,030	170	35,355	105,759	0.89	0.995
Average	106,597	26,354	20,967	394	4,366	11,679	22,315	75,687	944	158	34,860	80,958	0.71	0.994

Table 4.14. Farmed Lands Annual Water Balance Results, 1999-2019.

Water Year	Inflows (af)				Outflows (af)						Change in Storage (af)	Performance Indicators		
	Deliveries	Precipitation	Shallow Groundwater Interception	Groundwater Pumping	ET of Applied Water	ET of Precipitation	Deep Percolation of Applied Water	Deep Percolation of Precipitation	Runoff of Precipitation	Tailwater		Deliveries (af/ac)	Surface Water Supply Fraction	Crop Consumptive Use Fraction
1999	93,707	43,660	2,910	16,360	60,306	28,861	21,627	12,300	5,741	28,112	-308	5.37	0.85	0.55
2000	97,041	57,372	2,910	17,657	63,695	28,117	25,898	15,731	12,158	29,112	269	5.69	0.85	0.56
2001	88,163	44,546	2,910	19,058	62,907	26,903	21,288	10,376	6,908	26,449	-154	5.25	0.82	0.59
2002	93,008	53,042	2,910	19,820	63,499	26,946	25,218	14,523	11,256	27,902	-564	5.56	0.82	0.56
2003	65,386	62,507	2,910	16,437	46,829	31,055	19,531	14,227	15,071	19,616	911	4.74	0.80	0.57
2004	88,730	51,026	2,910	20,944	63,829	24,759	24,017	15,107	12,078	26,619	-2,799	5.15	0.81	0.58
2005	75,402	61,430	2,910	17,702	52,405	32,438	21,564	14,613	11,575	22,621	2,230	4.43	0.81	0.56
2006	78,828	74,496	2,910	18,228	52,156	31,954	23,994	22,441	19,756	23,648	513	4.70	0.81	0.54
2007	97,143	31,965	2,910	26,747	75,358	22,721	22,120	4,815	4,252	29,143	357	5.66	0.78	0.61
2008	81,634	40,569	2,910	24,615	63,655	23,211	21,668	9,389	8,411	24,490	-1,096	5.88	0.77	0.60
2009	77,150	39,842	2,910	28,892	67,194	23,728	21,957	6,873	7,133	23,145	-1,235	4.39	0.73	0.63
2010	62,188	55,918	2,910	24,453	49,769	29,870	20,297	13,208	11,056	18,656	2,614	4.54	0.72	0.57
2011	64,447	76,000	2,910	18,800	47,952	36,166	22,258	21,244	15,970	19,334	-766	3.79	0.77	0.58
2012	74,170	45,058	2,910	25,095	57,911	29,436	20,418	10,077	7,455	22,251	-314	5.48	0.75	0.58
2013	82,153	33,471	2,910	36,697	75,064	20,716	23,195	6,821	4,640	24,646	150	5.02	0.69	0.63
2014	73,817	19,599	2,910	36,184	68,952	16,011	20,320	2,602	1,526	22,145	954	5.44	0.67	0.63
2015	59,933	36,138	2,910	38,519	58,789	23,181	18,773	7,760	8,019	9,758	11,219	5.09	0.61	0.60
2016	66,920	57,081	2,910	24,714	55,676	28,613	18,985	12,281	13,806	20,091	2,175	5.05	0.73	0.61
2017	54,571	94,216	2,910	15,373	43,046	33,950	21,101	25,492	29,115	16,371	-2,003	5.04	0.78	0.62
2018	48,357	47,456	2,910	20,123	45,451	27,108	13,026	7,575	10,886	14,507	293	6.02	0.71	0.66
2019	66,675	89,606	2,910	17,313	47,261	34,849	20,933	21,565	28,443	20,003	3,451	5.45	0.79	0.56
Minimum	48,357	19,599	2,910	15,373	43,046	16,011	13,026	2,602	1,526	9,758	-2,799	3.79	0.61	0.54
Maximum	97,143	94,216	2,910	38,519	75,358	36,166	25,898	25,492	29,115	29,143	11,219	6.02	0.85	0.66
Average	75,687	53,095	2,910	23,035	58,176	27,647	21,342	12,810	11,679	22,315	757	5.13	0.77	0.59

Characterization of Water Management and Performance

<u>District</u>

Monthly inflow and outflow patterns provide insight into water management at the district-scale, which is influenced by water management and irrigation practices for the major crops grown, orchards and rice. The observed monthly patterns are expected to differ from individual fields, reflecting the full population of fields in the district.

Diversions begin in April or May and continue at relatively steady levels through August, when they decrease as fields are prepared for harvest, including draining of rice fields. Diversions continue in October and November for late orchard irrigation and to flood rice fields for decomposition and habitat. Diversions cease in mid-January in preparation for the next year's rice crop. Surface inflows, primarily from Snake Creek, tend to follow a similar pattern to diversions, as they result largely from upstream irrigation, demonstrating the "cascading" characteristic of irrigation in the region, where return flows from upstream water users are available for downstream agricultural and environmental uses.

Monthly ET generally follows the pattern of ET_o, increasing in the spring and summer as temperatures and available solar radiation increase, and decreasing in the winter. Actual ET rates are relatively similar to reference values due to the availability of adequate surface water supplies to support crop growth. Deep percolation and seepage are relatively constant over time due to the use of available surface water during the majority of the year, with deep percolation increasing somewhat in the winter as a result of precipitation and decreasing prior to planting and following harvest. Surface outflows follow the general pattern of diversions, increasing during irrigation.

The monthly change in storage reflects rice growing and winter flooding as well, with water going into storage in April and May, remaining relatively constant in June and July, and returning to the system as fields are drained in August and September. Storage then increases again October through December and is drained in January through February in preparation for planting.

On a water use basis, substantial recharge of the groundwater system occurs as a result of the use of surface water within BWD. It is estimated that approximately 39,000 af of groundwater recharge net of groundwater pumping and shallow groundwater interception occur annually within the district. It is estimated that approximately 7,000 af of shallow groundwater interception occurs annually. Groundwater interception supports the growth of native vegetation and provides base flow for streams and drains.

Comparing total inflows to BWD to total outflows to meet consumptive irrigation demands plus recoverable return flows available for use by others or the environment, a Water Management Fraction (WMF) may be calculated[8]. This indicator describes the amount of the total water supply not lost irrecoverably to evaporation from the canal and drain system (Equation 4.2).

[8] The WMF is based on methodologies to quantify the efficiency of agricultural water use developed by DWR (DWR 2012b) and has been broadened to include all beneficial ET as well as all water supplies.

$$\textit{Water Management Fraction} = \frac{\textit{Evapotranspiration} + \textit{Return Flows}}{\textit{Inflows}} \quad [4.2]$$

Over the period from 1999 to 2019, the WMF was 0.994, indicating that essentially all available water supply is used to meet irrigation demands or is recoverable for downstream surface water and groundwater uses.

Distribution and Drainage System

Inflows to the distribution and drainage system in the BWD service area include diversions from the Sutter-Butte Canal (which originates at Thermalito Afterbay), precipitation falling directly into canals and drains, inflows from BWGWD via Snake Creek, runoff of precipitation from farmed lands, shallow groundwater interception, and tailwater inflows from farmed lands. Outflows include deliveries, surface outflows to SEWD and BWGWD, seepage, evaporation, and riparian ET.

The objective of BWD operations is to meet the irrigation and environmental water demands of its customers. The water balance results indicate several characteristics of water management by BWD, its customers, and other water users in the district boundary but not served by the district. Comparing total deliveries to meet irrigation demand to diversions provides a measure of the effectiveness of system operation. A Delivery Fraction (DF), representing the ratio of deliveries to diversions may be calculated to provide an indicator of distribution and drainage system performance (Equation 4.3)[9].

$$\textit{Delivery Fraction} = \textit{Deliveries/Diversions} \quad [4.3]$$

The DF ranged from 0.46 to 0.89 between 1999 and 2019 with an overall average of 0.71. DF values increase as a result of limiting operational spillage and recovery and reuse of available water in the system by individual water users.

Farmed Lands

Inflows to the farmed lands include deliveries[10], groundwater pumping from private wells, and precipitation. Outflows include ET, tailwater, runoff of precipitation, and deep percolation. Additionally, as discussed previously, appreciable changes in stored water in the surface layer occur within the district as a result of rice production and winter flooding.

The objective of irrigation in BWD is to meet crop and environmental water demands in the most effective and efficient manner practical. Like the distribution and drainage system water balance, the farmed lands water balance provides insight into water management by BWD and growers.

Comparing total surface water supply (other than precipitation falling on farmed lands) to total irrigation supply including groundwater pumping, a surface water supply fraction (SWSF) may be

[9] Although the surface water supply includes sources other than diversions (e.g., precipitation inflows), the DF is calculated to include only diversions as this is the portion of surface water supply directly managed by BWD.
[10] As described previously, deliveries include deliveries by BWD and reuse by individual water users.

calculated as an indicator of the relative amount of the total irrigation supply derived from surface water (Equation 4.4).

$$Surface\ Water\ Supply\ Fraction = Deliveries \ / \ (Deliveries + Groundwater\ Pumping) \quad [4.4]$$

The SWSF ranged from approximately 0.61 to 0.85 between 1999 and 2019 with an average value of 0.77. This value demonstrates the reliability of and reliance on surface water supplies within BWD. In the rare event of reduced surface water allocations due to surface water shortages, private groundwater pumping can be increased to some extent to minimize lost production, resulting in decreased SWSF for those years. Even in years of reduced supply, surface water is the primary water source to meet demands.

Comparing crop ET_{aw} to total irrigation supplies, a crop consumptive use fraction (CCUF) may be calculated as an indicator of the relative amount of applied irrigation water consumed to grow the crop (Equation 4.5) (DWR 2012b).

$$\begin{aligned} &Crop\ Consumptive\ Use\ Fraction \\ &\qquad = Crop\ ET\ of\ Applied\ Water \ / \ (Deliveries + Groundwater\ Pumping) \end{aligned} \quad [4.5]$$

Between 1999 and 2019, the CCUF ranged from 0.54 to 0.66 with an overall average of 0.59. These CCUF values are calculated at the field scale and thus are not reflective of water reuse within the district. Based on estimated reuse of approximately 25,000 af of surface water by individual water users annually, the average CCUF at the district scale is estimated to be 0.85[11].

4.8 Climate Change

Climate change has the potential to directly impact surface water resources in the Feather River region and to indirectly impact groundwater resources. Due to the similarity in the nature of diversion agreements with the State among the primary water suppliers relying on the Feather River and due to similarity in cropping, climate, soils, and other factors, potential effects of climate change, impacts on water management, and actions by individual suppliers or through regional coordination to help mitigate future impacts are described for the region as a whole in Volume I, Section 5 of this regional AWMP. In particular, the following are discussed:

- Potential effects of climate change within the region;
- Resulting potential impacts on water resources including water supply, water demand, water quality, and flood control;
- Ongoing and potential future actions to help mitigate future impacts; and
- Additional resources regarding water resources planning to address climate change.

[11] Estimated as annual ET_{aw}/(deliveries + groundwater pumping – private reuse).

4.9 Efficient Water Management Practices and Water Use Efficiency

4.9.1 Efficient Water Management Practices

BWD seeks to efficiently manage water supplies to meet water management objectives, considering operational and financial constraints. Although supplying water to less than 25,000 acres, similar to other water supplier in the region, BWD implements technically feasible Efficient Water Management Practices (EWMPs) at locally cost-effective levels. Activities related to each of the EWMPs being implemented are summarized in Table 4.15. Water use efficiency improvements achieved through these activities may include increased local and statewide water supplies and water supply reliability, increased local flexibility, increased in-stream flow, improved water quality, and improved energy efficiency.

In 2003, BWD worked with DWR and Western Development and Storage to prepare a comprehensive evaluation of historical conserved water (BWD 2003). The evaluation considered both consumptive and non-consumptive uses of water within the district and provided a detailed analysis of historical consumptive and non-consumptive water use. Conserved water volumes were estimated based on changes in land use, cropping, and irrigation practices over time.

Other notable water management actions that BWD has implemented include the following:

- Provision of flexible deliveries for the range of crops grown and irrigation methods employed;
- Participated in a study evaluating restoration and recharge projects within the Butte County Groundwater Basins, specifically utilizing dual-source irrigation systems to promote in-lieu recharge[12];
- Support of on-farm physical and management improvements;
- Installation of flow measurement equipment at the Lateral 4 and Chandon lateral headings and replacement of flow measurement equipment at two additional sites;
- Implementation of a SCADA system for real-time monitoring of key district inflow and outflow sites;
- Installation of two partially-automated and one fully-automated control structures along Sutter-Butte canal to improve service and reduce spillage;
- Evaluation of opportunities to further improve service through automation of control structures and flow measurement in key locations;
- Conversion of open ditches to pipelines in areas with seepage issues;
- Recovery of drainwater into the distribution for reuse at two locations;
- Evaluation of opportunities to improve delivery of surface water to drip and microsprinkler irrigation systems on orchards, to maintain surface water customer base for local and regional sustainability; and

[12] Technical Report "Evaluation of Restoration and Recharge Within the Butte County Groundwater Basins" (https://www.buttecounty.net/wrcdocs/Reports/SpecialProjects/GWRecharge/Recharge_Eval.pdf)

- Ongoing coordination with DWR operations and other water management entities to evaluate and improve policies to allow for more flexible deliveries and storage.

As part of this plan, reconnaissance level cost estimates have been prepared for potential future water management improvements identified during field visits and meetings with BWD staff. Additionally, potential benefits of the improvements have been estimated. These improvements will be implemented over time as determined to be locally cost effective or to meet regional and statewide water management objectives as applicable given the flow-through nature of water management in the region, whereby water not consumed is available for reuse by downstream water users and the environment, and as funding becomes available from internal or other sources. The evaluation of potential water management improvements is included in Section 4.10.3. Additionally, opportunities to improve the joint facilities used to convey water from the afterbay to BWD have been evaluated and are described in Section 10.1.

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Table 4.15. EWMP Implementation Status.

Water Code Reference No.	EWMP	Implementation Status	Implemented Activities	Planned Activities
10608.48.b(1)	Measure the volume of water delivered to customers with sufficient accuracy to comply with subdivision (a) of Section 531.10 and to implement paragraph (2).	Not Required	• Deliveries are measured in a manner to support effective water management and equitable billing. • Evaluated customer delivery measurement options.	• Continue existing practices. • Consider customer delivery measurement improvements, contingent on availability of funding and project prioritization.
10608.48.b(2)	Adopt a pricing structure for water customers based at least in part on quantity delivered.	Being Implemented	• Irrigation events are limited as reasonable by crop type, with additional charges for subsequent irrigation deliveries. • Developed customer accounting and reporting system with billing capabilities that could be adapted for other pricing structures.	• Continue existing pricing.
10608.48.c(1)	Facilitate alternative land use for lands with exceptionally high water duties or whose irrigation contributes to significant problems, including drainage.	Not Technically Feasible	Lands with exceptionally high water duties or whose irrigation contributes to significant problems are not found within the BWD. Furthermore, BWD's rules and regulations prohibit wasteful use of water, preventing exceptional water duties or significant problems from occurring. Water applied but not consumed to produce crops provides beneficial groundwater recharge or is available for downstream uses.	
10608.48.c(2)	Facilitate use of available recycled water that otherwise would not be used beneficially, meets all health and safety criteria, and does not harm crops or soils	Not Technically Feasible	• There is no available water from municipal or industrial uses that meets all health and safety criteria within the service area.	• BWD is willing to consider opportunities for use of available recycled water if it meets all health and safety criteria.
10608.48.c(3)	Facilitate financing of capital improvements for on-farm irrigation systems	Being Implemented	• BWD provides at-cost labor and materials to assist landowners in improving on-farm irrigation systems. • BWD evaluated opportunities to maintain and increase surface water customer base for growers using pressurized irrigation. • Support growers to apply for NRCS funding to improve on-farm irrigation systems as lands are converted from rice to orchards.	• Continue to provide at-cost labor and materials for on-farm improvements, as resources allow. • Encourage landowners and growers to use available surface water through improved delivery to pressurized irrigation systems or other means.
10608.48.c(4)	Implement an incentive pricing structure that promotes one or more of the following goals: (A) More efficient water use at farm level, (B) Conjunctive use of groundwater, (C) Appropriate increase of groundwater recharge, (D) Reduction in problem drainage, (E) Improved management of environmental resources, (F) Effective management of all water sources throughout the year by adjusting seasonal pricing structures based on current conditions.	Being Implemented	• BWD water rates promote goal A by limiting irrigation events to the reasonable amount as determined by crop type, with additional charges for irrigation deliveries above a specified amount. • BWD water rates promote goals B and C by encouraging the use of available surface water supplies, which provides beneficial groundwater recharge through deep percolation. Groundwater is then available in years of surface water shortage while maintaining long term sustainability of the groundwater system. • BWD water rates promote goal E by providing a reliable, affordable source of water to maintain waterfowl habitat, primarily winter flooding of rice fields.	• Continue to promote goals A, B, C, and E through current water rates.

Water Code Reference No.	EWMP	Implementation Status	Implemented Activities	Planned Activities
10608.48.c(5)	Expand line or pipe distribution systems, and construct regulatory reservoirs to increase distribution system flexibility and capacity, decrease maintenance and reduce seepage	Being Implemented	• BWD evaluated small-scale conversions from open ditches to pipelines. • BWD has installed approximately 3,000 feet of pipeline in areas with seepage problems within the district since 2010. Additionally, a similar amount of pipeline was installed in the preceding decade. • BWD has evaluated lining along the Sutter-Butte canal; however, it is not locally cost effective at this time. Also, any seepage reduction from canal lining would reduce beneficial groundwater recharge. • Converted smaller open ditches to pipelines to reduce seepage and maintenance costs.	• Continue pipeline installations in areas with seepage problems as appropriate and as time and funding allow.
10608.48.c(6)	Increase flexibility in water ordering by, and delivery to, water customers within operational limits	Being Implemented	• BWD provides a high degree of flexibility to customers by providing orders with 24-hour notice, in most cases. • BWD evaluated opportunities to further improve service through comprehensive modernization including automation of control structures along Sutter-Butte canal, enhancement of conveyance capacity, and flow measurement at lateral headings. • BWD evaluated opportunities to maintain and increase surface water customer base for growers using pressurized irrigation through enhanced delivery service. • Improved four check structures (i.e., Holmes, Onslott, Thresher, and Pennington) with automation and/or remote monitoring with SCADA system. • Automated three out of eight check structures along the Sutter-Butte supply canal. • Installed flow measurement at the Lateral 4 and Chandon lateral headings, additionally replaced measurement equipment at two sites (i.e., Sutter-Butte canal downstream of Looney weir and upstream of Sunset Pumps).	• Explore funding options and proceed with automation, increased conveyance capacity, and flow measurement improvements, contingent on availability of funding and project prioritization. Encourage landowners and growers to use available surface water through improved delivery to pressurized irrigation systems or other means. • Replacing Looney Weir as part of SEWD's efforts to increase capacity of the Sutter-Butte canal. Project is in the design/permitting phase as of December 2020.
10608.48.c(7)	Construct and operate supplier spill and tailwater recovery systems	Being Implemented	• Drainwater recovery into the distribution system for reuse can currently be accomplished via pumping in two locations within BWD; however, individual BWD water users currently rely on the drainwater as a source of supply. • BWD installed two partially-automated and one fully-automated control structures along Sutter-Butte canal to improve service and reduce spillage. • BWD evaluated further automation of Sutter-Butte canal and flow measurement at lateral headings, which will reduce operational spillage. • BWD and the other Joint Districts implemented a SCADA system to allow for real time monitoring of Sutter-Butte Canal flows and operational spillage at Cox Spill.	• Continue drainwater recovery into the distribution system for reuse, as appropriate. • Install an additional automated structure along Sutter-Butte canal at Pennington Weir. • Explore options and proceed with automation and flow measurement improvements, contingent on availability of funding and project prioritization. Potential sites include: Cox Spill and other primary operational spill sites.

Water Code Reference No.	EWMP	Implementation Status	Implemented Activities	Planned Activities
10608.48.c(8)	Increase planned conjunctive use of surface water and groundwater within the supplier service area	Being Implemented	• An adequate amount of surface water is available for irrigation in most years. During shortage years, groundwater is used conjunctively with reduced surface water supplies to meet demand. • Shortage allocation policies are designed to facilitate the conjunctive use of groundwater in surface water shortage years. • BWD participates in voluntary groundwater substitution transfers to increase statewide water supplies. • BWD has chosen to implement SGMA as a GSA and is actively coordinating with other water managers in the subbasins it overlies. • Worked with Butte County to evaluate the feasibility of dual source irrigation systems to promote in-lieu recharge.	• Continue usage of surface water when available and conjunctive use of surface water and groundwater during periods of shortage to meet demand. • Encourage landowners and growers to use available surface water through improved delivery to pressurized irrigation systems or other means. • Continue voluntary groundwater substitution transfers. • Continue to implement SGMA as a GSA.
10608.48.c(9)	Automate canal control structures	Being Implemented	• Evaluated automation of Sutter-Butte canal as part of comprehensive modernization plan. • BWD installed two partially-automated and one fully-automated control structures along Sutter-Butte canal.	• Install an additional automated structure along Sutter-Butte canal at Pennington Weir. • Explore options and proceed with automation along Sutter-Butte canal, contingent on availability of funding and project prioritization.
10608.48.c(10)	Facilitate or promote customer pump testing and evaluation	Being Implemented	• BWD has developed a website, in part to promote available programs regarding pump testing and evaluation through links on the website and through communication with landowners and growers. • BWD requires flowmeters on private groundwater pumps used to pump water into the distribution system during curtailment years, which supports pump performance evaluation.	• Continue promoting customer pump testing and evaluation through available programs. • Continue requiring flowmeters on private groundwater pumps used to pump water into the distribution system during curtailment years.
10608.48.c(11)	Designate a water conservation coordinator who will develop and implement the water management plan and prepare progress reports.	Being Implemented	• The general manager serves as water conservation coordinator and is responsible for implementing AWMP.	• The general manager will continue to serve as water conservation coordinator.
10608.48.c(12)	Provide for the availability of water management services to water users.	Being Implemented	• BWD promotes awareness of water management services such as CIMIS and Federal Conservation Programs through links on their website and through communication with landowners and growers. • BWD holds annual meetings to discuss available water management services and other issues of interest with landowners and growers. • BWD provides at-cost labor and materials for on-farm improvements, subject to resource availability. • BWD evaluated opportunities to maintain and increase surface water customer base for growers using pressurized irrigation through enhanced delivery service.	• Continue promoting available water management services and holding annual meetings. • Continue to provide at-cost labor and materials for on-farm improvements. • Encourage landowners and growers to use available surface water through improved delivery to pressurized irrigation systems or other means.

Water Code Reference No.	EWMP	Implementation Status	Implemented Activities	Planned Activities
10608.48.c(13)	Evaluate the policies of agencies that provide the supplier with water to identify the potential for institutional changes to allow more flexible water deliveries and storage.	Being Implemented	• Conducts ongoing interactions with DWR SWP operations. • BWD is a voluntary participant in ACWA, NCWA, BCWC, and BBWUA. • BWD is a voluntary participant in NSVIRWMP. • BWD is a voluntary participant in FRRAWMP. • BWD participates in Joint District interactions with SWP operations. • BWD completed a comprehensive conservation study in 2003 in cooperation with DWR to quantify historical water savings (i.e., water left in storage) through conservation by the district and its water users. • BWD is implementing SGMA as a GSA. • Actively involved in Voluntarily Agreement discussions with the State.	• Continue interactions with DWR SWP operations. • Continue to evaluate policies of agencies that provide BWD with water. • Continue to participate in local, regional, and statewide committees and associations. • Continue to participate in local and regional planning initiatives.
10608.48.c(14)	Evaluate and improve the efficiencies of the supplier's pumps.	Being Implemented	• BWD regularly inspects district wells and performs maintenance and repairs as appropriate. • BWD inspects and repairs drainwater recovery pumps as necessary.	• Continue to inspect, maintain, and repair pumps as necessary.

4.9.2 Evaluation of Water Use Efficiency Improvements

CWC §10608.48(d) requires that AWMPs include:

> *… a report on which efficient water management practices have been implemented and are planned to be implemented, an estimate of the water use efficiency improvements that have occurred since the last report, and an estimate of the water use efficiency improvements estimated to occur five and 10 years in the future.*

A description of EWMPs that have been implemented by BWD has been provided previously in Section 4.9.1. This section provides an evaluation of EWMP implementation and an estimate of water use efficiency (WUE) improvements that have occurred in the past and are expected to occur in the future.

The value of evaluating water use efficiency (WUE) improvements (and EWMP implementation in general) from BWD's perspective is to identify what the benefits of EWMP implementation are and to identify those additional actions that hold the potential to support and advance the district's water management objectives. BWD's water management objectives include the long term reliability, quality, and affordability of local surface water and groundwater supplies and providing the best possible service its customers. To that end, BWD has taken action to develop and maintain reliable surface water and groundwater supplies, to prevent or reduce losses from the distribution system in order to increase operational efficiency, to promote the efficient use of water at the farm level, and to meet changing environmental and other demands that affect the flexibility with which the district can deliver water. BWD's water management activities are consistent with these objectives and have resulted in substantial local and statewide benefits.

First and foremost among the issues that must be considered in any evaluation of the benefits of EWMP implementation and resulting WUE improvements is how water management actions affect the water balance (Davenport and Hagan, 1982; Keller, et al., 1996; Burt, et al., 2008; Clemmens, et al., 2008; Canessa, et al., 2011). Accordingly, any evaluation of EWMP implementation and WUE improvements for BWD must consider how water balance changes relate to the district's water management objectives. For example, flows to deep percolation and seepage that could be considered losses in some settings are critical to maintain the long-term sustainability of the underlying groundwater basin. Reductions in these flows resulting from EWMP implementation could be considered WUE improvements at the farm or district scale, but have the consequential effect of diminishing recharge of the underlying groundwater system. Other flows that could be considered losses at the farm or district scale such as spillage and tailwater are also recoverable. For example, spillage from the BWD distribution and drainage systems is available for beneficial use by downgradient water users. The only distribution and drainage system or on-farm losses that are not recoverable within the BWD service areas, the underlying groundwater basin, or the Feather River region as a whole are canal and drain water surface evaporation. These components represent a small portion of BWD's water supply (less than one percent as indicated previously). An implication of this is that very little "new" water can be made available through water conservation in BWD's service area to increase overall water supply; however, there may be opportunities to change the timing and amount of water used to meet local, regional, or statewide objectives, as discussed in Volume I, Section 3 of this AWMP.

An important step in evaluating EWMP implementation and water use efficiency improvements is a comprehensive, quantitative, multi-year water balance (see Section 4.7). The quantitative understanding of the water use enables identification of targeted flow paths for WUE improvements, along with improved understanding of the beneficial impacts and consequential effects of EWMP implementation at varying spatial and temporal scales. The water balance enables evaluation of potential changes in water use amounts and timing for any given change in water management.

Even where comprehensive, multi-year water balances have been developed, evaluating water balance impacts and WUE improvements is not a trivial task. Issues of spatial and temporal scale and relatively small changes in flow paths resulting from many water management improvements (relative to day to day and year to year variation in water diversions and use) coupled with inaccuracies inherent in even the best water measurement greatly complicate the evaluation of water balance impacts. The implications of recoverable and irrecoverable losses at varying scales further complicate the evaluation of WUE improvements, and consequential, potentially unintended effects must be considered.

As part of assembling this AWMP, BWD has identified the targeted flow paths associated with implementation of each EWMP, the water management benefits of each EWMP and the potential consequential effects of implementation. A brief discussion of the benefits associated with implementation of each EWMP is provided, along with a brief discussion of consequential effects that must be considered. A summary of targeted flow paths, beneficial impacts, and consequential effects associated with implementation of each EWMP by BWD is provided in Table 4.16.

Table 4.16. Summary of WUE Improvements by EWMP.

Water Code Reference No.	EWMP	Implementation Status	Targeted Flow Path(s)	Benefits	Consequential Effects	Notes (See End of Table)
10608.48.b (1)	Measure the volume of water delivered to customers with sufficient accuracy.	Not Required	Deliveries, Spillage, Tailwater, Diversions, Drainage Outflows	Delivery measurement can encourage efficient on-farm water use, and has the potential to lead to reduced deliveries, dependent on pricing. Reduced deliveries result in reduced diversions, which result in corresponding reductions in spillage and drainage outflows. Available water not diverted remains in storage and can improve local supply reliability or could potentially be available for transfer. Additionally, water quality benefits may occur through reduced tailwater outflow.	Increased on-farm water use efficiency results in reduced tailwater available for reuse by downstream water users. For crops other than rice, increased on-farm efficiency results in reduced beneficial recharge to the groundwater system through deep percolation.	1
10608.48.b (2)	Adopt a pricing structure based at least in part on quantity delivered.	Being Implemented	Deliveries, Spillage, Tailwater, Deep Percolation, Diversions, Drainage Outflows	Pricing structures based on quantity delivered may result in increased efficiency of on-farm water use, which has the potential to lead to reduced deliveries. Reduced deliveries result in opportunities to expand agricultural production or surface water use within the service area, reduce groundwater pumping, or reduce diversions, which results in corresponding reductions in spillage and drainage outflows. Available water not diverted remains in storage and can improve local supply reliability or could potentially be available for transfer. Additionally, water quality benefits may occur through reduced tailwater outflow.	Increased on-farm water use efficiency results in reduced tailwater available for reuse by downstream water users. For crops other than rice, increased on-farm efficiency results in reduced beneficial recharge to the groundwater system through deep percolation.	1
10608.48.c (1)	Facilitate alternative land use for lands with exceptionally high water duties or whose irrigation contributes to significant problems, including drainage.	Not Technically Feasible	Not Applicable	Not Applicable	Not Applicable	2
10608.48.c (2)	Facilitate use of available recycled water that otherwise would not be used beneficially, meets all health and safety criteria, and does not harm crops or soils.	Not Technically Feasible	Not Applicable	Not Applicable	Not Applicable	2
10608.48.c (3)	Facilitate financing of capital improvements for on-farm irrigation systems.	Being Implemented	Deliveries, Spillage, Tailwater, Diversions, Groundwater Pumping, Drainage Outflows	Assisting in on-farm improvements through the provision of at-cost labor and materials can result in reduced deliveries due to increased delivery efficiency and/or reduced tailwater and, in some cases, deep percolation. Reduced deliveries result in opportunities to expand agricultural production or surface water use within the service area, reduce groundwater pumping, or reduce diversions, which results in corresponding reductions in spillage and drainage outflows. Available water not diverted remains in storage and can improve local supply reliability or could potentially be available for transfer. Additionally, water quality benefits may occur through reduced tailwater outflow.	Increased on-farm water use efficiency results in reduced tailwater available for reuse by downstream water users. For crops other than rice, increased on-farm efficiency results in reduced beneficial recharge to the groundwater system through deep percolation. Reduced operational spillage, tailwater, and drainage outflows result in reduced water available downstream for beneficial use for agriculture or the environment.	1

Water Code Reference No.	EWMP	Implementation Status	Targeted Flow Path(s)	Benefits	Consequential Effects	Notes (See End of Table)
10608.48.c (4)	Implement an incentive pricing structure that promotes one or more of the following goals: (A) More efficient water use at farm level, (B) Conjunctive use of groundwater, (C) Appropriate increase of groundwater recharge, (D) Reduction in problem drainage, (E) Improved management of environmental resources, (F) Effective management of all water sources throughout the year by adjusting seasonal pricing structures based on current conditions.	Being Implemented	Varies	BWD's pricing structure promotes goal (A), resulting in on-farm benefits as described for the volumetric pricing EWMP (10608.48.b(2)). Provision of surface water at lower rates than the cost of groundwater pumping incentivizes goals (B) and (C) and improves the reliability of regional water supplies while maintaining and enhancing ecosystems. Provision of water at affordable rates incentivizes goal (E) by offering a reasonably priced, reliable source of water to maintain waterfowl habitat, primarily winter flooding of rice fields.	Consequential effects of pricing structures based on quantity delivered are the same as described for the volumetric pricing EWMP (10608.48.b(2)).	1
10608.48.c (5)	Expand line or pipe distribution systems, and construct regulatory reservoirs to increase distribution system flexibility and capacity, decrease maintenance and reduce seepage.	Being Implemented	Deliveries, Spillage, Tailwater, Deep Percolation, Seepage, Diversions, Drainage Outflows	Benefits of lining, pipeline, and regulating reservoirs are reductions in losses such as seepage, operational spillage, and drainage outflows. In addition, regulating reservoirs provide improved consistency in deliveries, potentially providing a modest reduction in on-farm deliveries due to reduced tailwater and, in some cases, deep percolation and tailwater. Due to the proximity of the district's system to Thermalito Afterbay and heavy soils, which limit seepage losses, these benefits do not outweigh the costs at this time. Water quality benefits may occur through reduced tailwater outflow.	Reduced seepage and deep percolation result in reduced beneficial recharge of the underlying groundwater system. Reduced operational spillage, tailwater, and drainage outflows result in reduced water available downstream for beneficial use for agriculture or the environment.	1
10608.48.c (6)	Increase flexibility in water ordering by, and delivery to, water customers within operational limits.	Being Implemented	Deliveries, Spillage, Tailwater, Deep Percolation, Diversions, Drainage Outflows	Flexible water ordering and deliveries result in reduced operational spillage, tailwater, and, in some cases, seepage and deep percolation. It can also result in a modest reduction in deliveries due to on-farm reductions in tailwater and deep percolation. System improvements result in greater operational efficiency and reductions in spillage. Additionally, water quality benefits may occur through reduced tailwater outflow. In aggregate, reduced losses (both on-farm and at the district level) can lead to reduced deliveries. Reduced deliveries result in opportunities to expand agricultural production or surface water use within the service area, reduce groundwater pumping, or reduce diversions, which results in corresponding reductions in spillage and drainage outflows. Available water not diverted remains in storage and can improve local supply reliability or could potentially be available for transfer.	Increased on-farm water use efficiency results in reduced tailwater available for reuse by downstream water users. For crops other than rice, increased on-farm efficiency results in reduced beneficial recharge to the groundwater system through deep percolation. Reduced operational spillage, tailwater, and drainage outflows result in reduced water available downstream for beneficial use for agriculture or the environment.	1

Water Code Reference No.	EWMP	Implementation Status	Targeted Flow Path(s)	Benefits	Consequential Effects	Notes (See End of Table)
10608.48.c (7)	Construct and operate supplier spill and tailwater recovery systems.	Being Implemented	Deliveries, Spillage, Tailwater, Diversions, Drainage Outflows	Reuse of operational spillage and tailwater results in decreased required diversions. Available water not diverted remains in storage and can improve local supply reliability or could potentially be available for transfer. Additionally, water quality benefits may occur through reduced tailwater outflow.	Reduced operational spillage, tailwater, and drainage outflows result in reduced water available downstream for beneficial use for agriculture or the environment. Tailwater may be of diminished quality as compared to other available water supplies. Spillage and tailwater recovery using pumps requires the use of electricity or fuel as a component, increasing energy demand.	1
10608.48.c (8)	Increase planned conjunctive use of surface water and groundwater within the supplier service area.	Being Implemented	Diversions, Deliveries, Deep Percolation, Groundwater Pumping	Conjunctive management provides multiple benefits: • Maintain local and statewide water supply reliability • Enhance aquatic and wetlands ecosystems • Reduce energy requirements for irrigation Encouraging growers to use available surface water instead of groundwater provides beneficial groundwater recharge through deep percolation. Groundwater is then available in years of surface water shortage while maintaining the long term sustainability of the groundwater system.	Not Significant	1
10608.48.c (9)	Automate canal control structures.	Being Implemented	Deliveries, Spillage, Tailwater, Diversions, Drainage Outflows	Automation results in reduced operational spillage and reduced deliveries due to increased delivery efficiency, which reduces on-farm tailwater and, in some cases, deep percolation. Reduced deliveries result in opportunities to expand agricultural production or surface water use within the service area, reduce groundwater pumping, or reduce diversions, which results in corresponding reductions in spillage and drainage outflows. Available water not diverted remains in storage and can improve local supply reliability or could potentially be available for transfer. Additionally, water quality benefits may occur through reduced tailwater outflow.	Increased on-farm water use efficiency results in reduced tailwater available for reuse by downstream water users. For crops other than rice, increased on-farm efficiency results in reduced beneficial recharge to the groundwater system through deep percolation. Reduced operational spillage, tailwater, and drainage outflows result in reduced water available downstream for beneficial use for agriculture or the environment.	1
10608.48.c (10)	Facilitate or promote customer pump testing and evaluation.	Being Implemented	None	Improved pumping efficiency by BWD's customers results in decreased energy demand and reduced pumping costs for customers. There are no direct benefits to BWD.	Not Significant	
10608.48.c (11)	Designate a water conservation coordinator who will develop and implement the water management plan and prepare progress report.	Being Implemented	Varies	See Comment	See Comment	3
10608.48.c (12)	Provide for the availability of water management services to water users.	Being Implemented	Deliveries, Spillage, Tailwater, Diversions, Groundwater Pumping, Drainage Outflows	Promoting available water management services can increase efficiency of on-farm water use, which has the potential of leading to reduced deliveries. Reduced deliveries result in reduced diversions, which result in corresponding reductions in spillage and drainage outflows. Available water not diverted remains in storage and can improve local supply reliability or could potentially be available for transfer. Additionally, water quality benefits may occur through reduced tailwater outflow.	Increased on-farm water use efficiency results in reduced tailwater available for reuse by downstream water users. For crops other than rice, increased on-farm efficiency results in reduced beneficial recharge to the groundwater system through deep percolation. Reduced operational spillage, tailwater, and drainage outflows result in reduced water available downstream for beneficial use for agriculture or the environment.	1

Water Code Reference No.	EWMP	Implementation Status	Targeted Flow Path(s)	Benefits	Consequential Effects	Notes (See End of Table)
10608.48.c (13)	Evaluate the policies of agencies that provide the supplier with water to identify the potential for institutional changes to allow more flexible water deliveries and storage.	Being Implemented	Diversions	Increased flexibility and storage for the surface water supply could result in reductions in losses to operational spillage, tailwater, and drainage outflows. Additionally, water quality benefits may occur through reduced tailwater outflow.	Reduced operational spillage, tailwater, and drainage outflows result in reduced water available downstream for beneficial use for agriculture or the environment.	1
10608.48.c (14)	Evaluate and improve the efficiencies of the supplier's pumps.	Being Implemented	None	Improved pumping efficiency of BWD's pumps and prioritizing repairs or replacement based on pump evaluations results in decreased energy demand and reduced pumping costs for BWD and increases pump reliability. There are no direct impacts to water balance flow paths.	Not Significant	

Notes:

1. BWD works to balance tradeoffs between incentivizing water conservation (both districtwide and on-farm) and maintaining long-term surface water and groundwater reliability.
2. Such lands or conditions do not exist in BWD. As a result, it is not technically feasible to implement this EWMP.
3. Implementation of the AWMP by BWD's water conservation coordinator and other staff as appropriate is the mechanism by which all EWMPs are implemented and targeted benefits are realized.

WUE definitions vary. For purposes of evaluating WUE improvements associated with EWMP implementation by BWD, specific WUE improvement categories or objectives have been identified that correspond to each EWMP. Potential WUE improvements include reduction of irrecoverable losses, increased local supply, increased local flexibility, increased in-stream flow, improved water quality, and improved energy efficiency. Definitions for each of the WUE improvement categories have been developed and are provided in Table 4.17. Note that the WUE improvement categories are not mutually exclusive in many cases. For example, reductions in irrecoverable losses could be used to increase local supply. The applicability of each EWMP to each WUE improvement category based on BWD's water management activities has been identified and is presented in Table 4.18.

Table 4.17. WUE Improvement Categories.

Water Use Efficiency Improvement Category	Definition
Reduce Irrecoverable Losses	Reduce losses that cannot be recovered and used by the water supplier or downgradient users (e.g., evaporation and flows to salt sinks).
Increase Local Supply (and Supply Reliability)	Reduce losses and/or increase storage locally to increase supply available to meet demands, including both near-term (within an irrigation season) and long-term (over more than one year).
Increase Local Flexibility	Improve the supplier's ability to divert, pump, convey, control, and deliver available water supplies to meet customer demands.
Increase In-Stream Flow	Increase flow in natural waterways to benefit fisheries or meet other environmental objectives.
Improve Water Quality	Increase the quality of targeted water bodies (i.e., streams, lakes, or aquifers).
Improve Energy Efficiency	Increase the efficiency of water supplier or customer pumps.

In order to more explicitly report an estimate of WUE improvements and an estimate of WUE improvements expected to occur five and ten years in the future, BWD has estimated the qualitative magnitude (expressed as None, Limited, Modest, or Substantial in order of increasing relative magnitude) for the targeted flow paths associated with each EWMP relative to the applicable WUE improvement categories identified in Table 4.18. Past WUE improvements are estimated relative to no historical implementation. WUE improvements relative to the time of the last plan are not applicable as BWD has not previously prepared an AWMP. Future WUE improvements are estimated for five years in the future (2025) relative to 2020 and for ten years in the future (2030) relative to 2020. The result of this evaluation is provided in Table 4.19.

BWD will continue to seek out and implement water management actions that meet its overall water management objectives and result in WUE improvements. The continuing review of water management within BWD, coupled with exploration of innovative opportunities to improve water management will result in future management improvements by the district and additional WUE improvements.

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Table 4.18. Applicability of EWMPs to WUE Improvement Categories.

Water Code Reference No.	EWMP	Implementation Status	Potential Water Use Efficiency Improvement Category: Reduce Irrecoverable Losses	Increase Local Supply	Increase Local Flexibility	Increase In-Stream Flow	Improve Water Quality	Improve Energy Efficiency[1]
10608.48.b (1)	Measure the volume of water delivered to customers with sufficient accuracy.	Not Required		✓		✓	✓	✓
10608.48.b (2)	Adopt a pricing structure based at least in part on quantity delivered.	Being Implemented		✓		✓	✓	
10608.48.c (1)	Facilitate alternative land use for lands with exceptionally high water duties or whose irrigation contributes to significant problems, including drainage.	Not Technically Feasible	Not Applicable to BWD					
10608.48.c (2)	Facilitate use of available recycled water that otherwise would not be used beneficially, meets all health and safety criteria, and does not harm crops or soils.	Not Technically Feasible	Not Applicable to BWD					
10608.48.c (3)	Facilitate financing of capital improvements for on-farm irrigation systems.	Being Implemented		✓		✓	✓	✓
10608.48.c (4)	Implement an incentive pricing structure that promotes one or more of the following goals: (A) More efficient water use at farm level, (B) Conjunctive use of groundwater, (C) Appropriate increase of groundwater recharge, (D) Reduction in problem drainage, (E) Improved management of environmental resources, (F) Effective management of all water sources throughout the year by adjusting seasonal pricing structures based on current conditions.	Being Implemented		✓		✓	✓	
10608.48.c (5)	Expand line or pipe distribution systems, and construct regulatory reservoirs to increase distribution system flexibility and capacity, decrease maintenance and reduce seepage.	Being Implemented		✓	✓	✓	✓	
10608.48.c (6)	Increase flexibility in water ordering by, and delivery to, water customers within operational limits.	Being Implemented		✓	✓	✓	✓	✓
10608.48.c (7)	Construct and operate supplier spill and tailwater recovery systems.	Being Implemented		✓	✓	✓	✓	
10608.48.c (8)	Increase planned conjunctive use of surface water and groundwater within the supplier service area.	Being Implemented		✓				
10608.48.c (9)	Automate canal control structures.	Being Implemented		✓	✓	✓	✓	
10608.48.c (10)	Facilitate or promote customer pump testing and evaluation.	Being Implemented						✓
10608.48.c (11)	Designate a water conservation coordinator who will develop and implement the water management plan and prepare progress report.	Being Implemented	The activities of the Water Conservation Coordinator and other BWD staff to achieve WUE improvements through implementation of the AWMP are described individually by EWMP.					
10608.48.c (12)	Provide for the availability of water management services to water users.	Being Implemented		✓		✓	✓	✓
10608.48.c (13)	Evaluate the policies of agencies that provide the supplier with water to identify the potential for institutional changes to allow more flexible water deliveries and storage.	Being Implemented		✓	✓	✓	✓	
10608.48.c (14)	Evaluate and improve the efficiencies of the supplier's pumps.	Being Implemented						✓

1. Includes reducing energy demands.

Table 4.19. Evaluation of Relative Magnitude of Past and Future WUE Improvements by EWMP.

Water Code Reference No.	EWMP	Imple-mentation Status	Marginal WUE Improvement[1,2]			
			Past		Future	
			Relative to No Historical Implementation[3]	Since Last AWMP[4]	5 Years in Future[5]	10 Years in Future[5]
10608.48.b (1)	Measure the volume of water delivered to customers with sufficient accuracy	Not Required	None	None	None to Substantial, Depending on Funding	
10608.48.b (2)	Adopt a pricing structure based at least in part on quantity delivered	Being Implemented	Limited	None	None to Substantial, Depending on Funding	
10608.48.c (1)	Facilitate alternative land use for lands with exceptionally high water duties or whose irrigation contributes to significant problems, including drainage.	Not Technically Feasible	Not Applicable to BWD			
10608.48.c (2)	Facilitate use of available recycled water that otherwise would not be used beneficially, meets all health and safety criteria, and does not harm crops or soils.	Not Technically Feasible	Not Applicable to BWD			
10608.48.c (3)	Facilitate financing of capital improvements for on-farm irrigation systems	Being Implemented	Limited	Limited	None	
10608.48.c (4)	Implement an incentive pricing structure that promotes one or more of the following goals: (A) More efficient water use at farm level, (B) Conjunctive use of groundwater, (C) Appropriate increase of groundwater recharge, (D) Reduction in problem drainage, (E) Improved management of environmental resources, (F) Effective management of all water sources throughout the year by adjusting seasonal pricing structures based on current conditions.	Being Implemented	Modest (Goals A, B, C & E)	Limited	None to Modest, Depending on Funding and Opportunities	
10608.48.c (5)	Expand line or pipe distribution systems, and construct regulatory reservoirs to increase distribution system flexibility and capacity, decrease maintenance and reduce seepage	Being Implemented	Modest	Limited	Limited to Modest, Depending on Funding and Opportunities	
10608.48.c (6)	Increase flexibility in water ordering by, and delivery to, water customers within operational limits	Being Implemented	Substantial	Modest	None to Modest, Depending on Funding	
10608.48.c (7)	Construct and operate supplier spill and tailwater recovery systems	Being Implemented	Modest	Limited	None to Modest, Depending on Funding	
10608.48.c (8)	Increase planned conjunctive use of surface water and groundwater within the supplier service area	Being Implemented	Substantial	Modest	None to Substantial, Depending on Funding and Opportunities	
10608.48.c (9)	Automate canal control structures	Being Implemented	Modest	Modest	None to Substantial, Depending on Funding	
10608.48.c (10)	Facilitate or promote customer pump testing and evaluation	Being Implemented	None	Limited	Limited	None
10608.48.c (11)	Designate a water conservation coordinator who will develop and implement the water management plan and prepare progress report.	Being Implemented	The activities of the Water Conservation Coordinator and other BWD staff to achieve WUE improvements through implementation of the EWMPs are described individually by EWMP.			
10608.48.c (12)	Provide for the availability of water management services to water users.	Being Implemented	Modest	Limited	Limited	None
10608.48.c (13)	Evaluate the policies of agencies that provide the supplier with water to identify the potential for institutional changes to allow more flexible water deliveries and storage.	Being Implemented	Modest	Substantial	None to Modest, Depending on Outcomes	
10608.48.c (14)	Evaluate and improve the efficiencies of the supplier's pumps.	Being Implemented	Substantial	Limited	None to Limited, Depending on Funding	

1. As noted herein and throughout this analysis, reductions in losses that result in WUE improvements at the farm or district scale do not typically result in WUE improvements at regional scale, except in the case of evaporation reduction. All losses to seepage, spillage, tailwater, and deep percolation are recoverable within the BWD service area or by downgradient water users. Opportunities to achieve WUE through changes to the timing and amounts of water use may exist in some cases.

2. Quantitative estimates of improvements are not available. Rather, qualitative estimates are provided as follows, in increasing relative magnitude: None, Limited, Modest, and Substantial.

3. WUE Improvements occurring in recent years relative to if they were not being implemented.
4. WUE Improvements occurring in recent years relative to the level of implementation at time of last AWMP. Not applicable, as BWD has not previously prepared an AWMP.

5. WUE Improvements expected in 2025 (five years in the future) and 2030 (ten years in the future), relative to level of implementation in recent years.

4.10 Attachments

This section includes the following attachments:

- 4.10.1 – Public Coordination and Adoption
- 4.10.2 – Rules and Regulations
- 4.10.3 – Potential Projects to Enhance Water Management Capabilities
- 4.10.4 – Drought Management Plan

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4.10.1 Resolution of Adoption

Documentation of adoption of this AWMP by its board of directors is provided on the following page.

RESOLUTION 2021-04

Resolution of the Board of Directors of Butte Water District to Adopt the Feather River Regional Agricultural Water Management Plan - 2020 Update

WHEREAS, the Board of Directors of Butte Water District ("Board") has caused the preparation of an Agricultural Water Management Plan 2020 Update; and

WHEREAS, Butte Water District provides water to less than 25,000 irrigated acres and is exempt from the requirements of the Agricultural Water Management Planning Act (Part 2.8 of Division 6 of the California Water Code) pursuant to section 10853 of the California Water Code; and

WHEREAS, Butte Water District has voluntarily elected to update its Agricultural Water Management Plan; and

WHEREAS, pursuant to section 10853 of the California Water Code, the Butte Water District is exempt from the notice and public hearing requirements of section 10841 of the California Water Code; and

WHEREAS, pursuant to Section 10851 of the California Water Code, the California Environmental Quality Act ("CEQA") does not apply to the preparation and adoption of the Plan.

NOW, THEREFORE, BE IT RESOLVED by the Board of Directors of Butte Water District that the Feather River Regional Agricultural Water Management Plan 2020 Update is hereby approved and adopted.

BE IT FURTHER RESOLVED that the Board is authorized to implement the adopted Plan in accordance with any schedules set forth therein, and to take all steps necessary to publish and submit the Plan.

PASSED AND ADOPTED this 11th day of November, 2021 at Gridley, California, by the following vote:

Ayes: 4 Etcheverry, Smith, Waller, Pantaleoni
Noes: Ø
Abstain: Ø
Absent: 1 Righero

BY ______________________
President of the Board

ATTEST: ______________________
Secretary to the Board

4.10.2 Rules and Regulations

BWD's rules and regulations are provided on the following pages.

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Butte Water District

BY-LAWS

and

RULES AND REGULATIONS FOR DISTRIBUTION OF WATER

OFFICE: 735 VIRGINIA STREET
GRIDLEY, CALIFORNIA 95948

Telephone 916-846-3110

Officer of the

BUTTE WATER DISTRICT

M.W. Carlin
Frank Hatamiya
Charles Herrington
Phillip Haynes
Robert Waller

SECRETARY
MANAGER
Lester Breeding

Gridley 3100

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TO THE LANDOWNERS AND WATER USERS OF THE BUTTE WATER DISTRICT:

Butte Water District is a State Agency governed by a board of directors elected by the people. It operates under the authority conferred by the Water Code. It makes no profit and is operated for the sole benefit of the lands and the people within its boundaries. The benefits they can derive from it will be measured by the extent to which the people within the district cooperate to make it a success.

These By-Laws, Rules and Regulations have been adopted by the Board of Directors under the authority of the Water Code and are a part of the law governing this District comparable to county or municipal ordinances.

All records of the District are open to public inspection during the hours when the office of the district is open to the public. All officials and employees will cheerfully furnish any information concerning the affairs of the district. LANDOWNERS ARE REQUESTED TO AVAIL THEMSELVES OF THIS SOURCE OF INFORMATION.

This booklet is available for free distribution.

BOARD OF DIRECTORS
of the
BUTTE WATER DISTRICT

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BY-LAWS of BUTTE WATER DISTRICT

ARTICLE I

The Board of Directors shall meet in regular session on the third Wednesday in each month, at the hour of 9:00 o'clock A.M. at the office of said District, provided, however, that the date and hour of holding such regular monthly meeting may be changed at any time by resolution of the Board of Directors entered on its minutes not less than thirty days prior to such change becoming effective. Every regular meeting and every special meeting may be adjourned from time to time and said adjourned meeting shall constitute a regular meeting or special meeting as the case may be.

Special meetings may be called, or held on consent of all directors, as provided by the California Water District Law, and when so called or held, any business of the District may be transacted whether notice that said business was to be acted upon at said special meeting, was given or not.

ARTICLE II

The office of said District shall be at 735 Virginia Street, Gridley, California but the location of said office may be changed by resolution entered on the minutes of the Board not less than thirty days before such change becomes effective.

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ARTICLE III

The Directors shall choose from among its members, a President to hold office at the pleasure of the board, who shall preside at all meetings of the Board and shall perform all other duties usually incumbent on such officer, and all duties required of him by law or order of the Board of Directors. In his absence or inability to act his duties shall devolve upon a temporary chairman to be selected from their own number by the other directors.

ARTICLE IV

The Board shall appoint a Secretary to hold office at the pleasure of the Board, who shall keep a full and correct record of the proceedings of the Board of Directors, and shall have charge af all books, maps, and papers of the District, except those required by the Assessor, Collector, Treasurer, or Manager. He shall perform all duties usually appertaining to such office, and those required by law or the order of the Board. The Secretary need not be a resident or holder of title to land in the District and his salary shall be fixed by resolution of the Board. The Board may by resolutton establish a bond for the Secretary to carry. The Board may employ an assistant Secretary to assist the Secretary in the administration of the affairs of his office.

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ARTICLE V

The offices of Assessor, Tax Collector and Treasurer of the District shall be consolidated into one office.

The person holding such office shall as Treasurer keep a full and correct record of the finances of the District. He shall keep, in a separate book for that purpose, a record of each warrant drawn by him, on order of the Directors, showing the date, number, the name of the person to whom and for what services the same was issued. He shall also perform all duties usually encumbent on such office and all duties required of him by law, and all duties required of him by the terms of the bonds issued by this District. He shall draw no warrants unless ordered by the Directors, except for salaries which have been fixed by the Board. He may, with the approval of the Board, appoint a deputy whose salary and bond if any, shall be fixed by the Board.

The person holding such consolidated office, shall as Assessor keep a full and correct record of all work done by him and shall do all things required of him to be done as provided by law.

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The person holding such consolidated office, shall as Tax Collector collect all taxes or assessments due the District and shall keep an accurate record thereof showing the amounts collected, on what parcels and from whom collected. He may, with the approval of the Board, appoint a deputy whose salary, and bond, if any, shall be fixed by the Board.

The salary for the consolidated office of Assessor, Tax Collector and Treasurer, shall be fixed by resolution of the Board, and said officer may be required to carry an official bond in such sum as may be fixed by the Board of Directors.

ARTICLE VI

The Board shall also employ a Manager of the District who shall attend to the maintenance and operation of the works of the District, and the distribution of water and such other duties as may be delegated to him by the Board. The salary of the Manager shall be fixed by resolution of the Board.

ARTICLE VII

The Directors, in addition to the powers conferred by law, shall have full power and authority to do any and all things necessary to effect the work of irrigation of lands of the District, and for the management and control of the same and of the affairs of the District.

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The Directors shall have such powers as are now or may be hereafter conferred on them by law. Each Director shall receive the sum of Twenty Dollars ($20.00) for each meeting he attends and for each day actually engaged in business of the District on order of the Board, and in addition his necessary actual expenses when on business for the District, but no mileage shall be paid for traveling to or from the Board meetings.

Prior to Feb. 15 of each year the Board shall by resolution adopt rules and regulations, not inconsistent herewith, for the operation of the District and sale and distribution of water, and fix the rates to be charged for water for that year.

ARTICLE VIII

All claims against the District shall be presented in writing, and filed with the Secretary.

ARTICLE IX

These By-Laws may be amended in the manner specified in Section 35305 of the Water Code as now worded or as the same may be hereafter amended.

ARTICLE X

Should a vacancy exist in any of the offices of the District, it may be filled by appointment by a majority of the Board of Directors.

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ARTICLE XI

All elected officers of the District shall hold office respectively for the period prescribed by law and until their successors are elected and qualified. Election of officers shall be held on the first Tuesday after the first Monday in November in each odd numbered year. The election shall be held and conducted and notice thereof shall be given as provided in Sec. 1, Part 3 (Uniform District Election Law Commencing With Section 23500) as added to Division 12 of the Election Code and part 4, Division 13 of the Water Code. For the purposes of said election there shall be but one election precinct the boundaries of which shall be coterminous with the boundaries of the District. Each holder of title or evidence of title shall have the right to vote at any and all elections held in the District.

RULES AND REGULATIONS

for the Distribution of Water

in the Butte Water District

and

Rates of Tolls and Charges

For the Use Thereof

Adopted: November 16, 1966

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DEFINITIONS AND GENERAL PROVISIONS

"DISTRICT" means Butte Water District functioning under the California Water District Law.

"BOARD" means the Board of Directors of District.

"SECRETARY" means the Secretary of the Board.

"MANAGER" means the Manager appointed by the Board.

"WORKS" includes dams, wells, conduits pumps and power plants.

"CONDUITS" includes canals, laterals, ditches, drains, flumes, pipes, measuring and control devices therein and their appurtenances.

"OPERATE" and "OPERATION" includes use, maintenance and repair.

"CONSUMER" includes water user, or user of other services of District.

"RULES" include regulations.

"CHARGES" include water tolls, and rates. The singular number includes the plural and the plural, the singular.

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RULE 1—WATER USE

District was organized for the purpose of supplying irrigation service for orchards and farm crops. The water quality and district facilities are not suitable for domestic use, raising of fish, or use for industrial or commercial purposes. Any service for purposes other than the growing of agricultural crops will only be provided on a special order of the Board of Directors entered in its minutes.

RULE 2—CONTROL OF SYSTEM

The operation of the works of the District shall be under the exclusive management and control of the Manager, and no other persons, except his employees and assistants, shall have any right to interfere with said works in any manner, except in case of an order from the Board.

RULE 3—DITCHTENDERS AND OTHER EMPLOYEES

The Manager will employ such ditchtenders and other assistants as he may deem necessary for the proper operation of the system subject to the approval of the Board.

RULE 4—CONTROL DEVICES

No gate, takeout, siphon or other structures or device shall be installed or placed in any conduit belonging to the District except in pursuance of plans adopted or orders made by the Board.

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RULE 5—UNAUTHORIZED USE OF WORKS

No person shall divert or take water from any conduit belonging to the District or under its control, or make any opening therein, or change, molest, disturb or interfere with any gate, takeout, or other structure or device in any such conduit without permission of the ditchtender in charge thereof or the Manager.

RULE 6—PRIVATE CONDUITS

All private conduits shall be maintained and kept clean by the users thereof at no cost to the District and shall be of sufficient size to carry the irrigation head ordered. The Manager, or his representative, may examine private conduits before water is turned in to determine whether the conduits are in proper condition to carry water. In case any conduit is found not to be in such proper condition, the water shall not be turned into it until the condition is corrected.

No person shall divert or take water through a private conduit by making an opening in a conduit belonging to the District or change, molest, disturb or interfere with any gate, takeout or any other structure or device in any District conduit without permission of the Ditchtender in charge thereof or the Manager.

Where a conduit must be constructed or enlarged to carry water from an existing

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District conduit to land to be served, the landowners or users requesting water must provide the right of way and construct or enlarge at no cost to the District a conduit from said land to a District conduit designated by the Manager and approved by the Board.

The Distrct shall have control of all diverting gates and weirs in private conduits to the extent necessary to enforce the delivery of water in accordance with these Rules, but the District shall not thereby assume or incur any liability for the operation of such gates and weirs. Only District employees or persons delegated by them shall have authority to open such diverting gates and weirs, and they shall have full authority to close such gates and weirs as soon as the proper amount of water for each irrigation has been discharged. Such gates and weirs may be equipped with locks, and the keys thereof shall be under the control of the Manager.

RULE 7—OWNERSHIP OF WATER

All water within the District is the property of the District and is subject to diversion and use by the District. No purchaser of water from the District acquires any proprietary right therein by reason of such use, nor does such purchaser acquire any right to re-sell such water, or to use it on premises or for a purpose other than for which it was applied and as stated in the

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application. The District expressly asserts the right to re-capture, re-use and resell all water that passes from the premises described in the application as the place of use, and asserts its right to all water within the District.

RULE 8—DISTRIBUTION OF WATER

Except as otherwise herein provided, all water shall be apportioned ratably to the land in the District, upon such landowners making proper application therefor under these rules and making payment of the charges fixed by the Board. Upon failure of any landowner to make application for water or pay charges, the water to which such landowner would be entitled may be alloted by the District to other landowners offering to make the required payments therefor.

RULE 9—APPLICATION FOR WATER

Landowner or user desiring water for annual crops or new plantings shall make application for water, at the District office. The application shall state the crops and acreage of each crop the applicant is intending to irrigate, and shall state the name of the owner, name of tenant, or tenants, acreage and location of acreage for which water is desired, and such other matters as the Board may deem necessary. Where the applicant is not the owner of the land on which the water is to be used, the District may require the landowner to also sign the

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application. The application shall grant a right to the Disrict to control all private conduits, and to install, maintain, control and regulate all meters, measuring devices, delivery gates or other structures in any private conduit necessary for the distribution, measurement and control of the water for which application is made. Provided, however, such control and rights shall not impose a duty to excerise the same, or liability for damages resulting from the use of such conduits or otherwise arising. The time within which applications for water must be made may be extended or changed by resolution or order of the Board of Directors.

RULE 10—DELIVERY OF WATER

All requests for water service must be made in writing on forms prepared by the District and must be delivered at the District's office or to the ditchtender in charge of the delivery at least twenty-four (24) hours before the water is needed. Effort will be made to make delivery as soon as reasonably practical.

All shut-off orders must be sent to the District office or given to the ditchtender not later than 5 o'clock P.M. on the day before such shut-off is desired. When service is desired for shorter periods than one day the shut-off order must accompany the request for service.

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Water must be used continuously by the water user throughout the period of delivery, both day and night.

RULE 11—FIXED RATES OF CHARGES

The rates of charges for the use of water, which may include a service charge and penalties and interest on delinquency and the time of payment of such charges may be fixed and determined annually by the Board prior to the fifteenth day of February of each year.

RULE 12—DISCONTINUING SERVICE FOR UNPAID CHARGES

If water charges are not paid when due the Board may, in its discretion, shut off the service of water until the charges are paid. This includes the right to shut off water regardless of the type of crop being irrigated or the use to which the water is being put and regardless of whether the user thereof is a landowner, tenant or other user.

In the event any water charges are unpaid at the end of an irrigation season on any particular land, the district may, in its discretion, refuse to serve water to that land in the following or subsequent seasons, until all such unpaid water charges are paid in full. This shall include the right to refuse service of water although the user of the

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water for which charges remain unpaid was not the owner of the land, and although the ownership of the land may have changed since the water for which the charges remain unpaid, was used.

In the event service of water is shut off as hereinbefore provided for, neither the Board, the District, or its officers, agents or employees, shall be liable for any damage that may occur as a result thereof.

RULE 13—LANDOWNERS RESPONSIBLE FOR WATER CHARGES

Landowners shall be responsible for all water charges not paid when the same become due regardless of whether or not the land is being rented, leased or farmed by other than the landowner, and regardless of the person or persons requesting and making application for water.

Nothing herein contained, however, shall deprive the District of any other rights it may have to enforce payment of charges.

RULE 14—ACREAGE SURVEYS

The District shall have the right to make a survey for the purpose of determining the acreage on which water was used, allowed to stand, and over which it is permitted to flow or drain. The Charges for water will be on the gross acreage covered with water regardless of acreage actually planted.

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RULE 15—ACKNOWLEDGMENTS

Whenever required by the District through its servants and employees, each landowner or water user, personally or through his agents, shall sign and deliver to the District a memorandum in writing acknowledging the acreage planted to each crop. If no survey is made by the District as hereinbefore provided, then said acknowledgment shall be binding upon the landowner and water user as to the acreage planted and type of crop. Any claim by a landowner or water user for a refund of water charges shall be made prior to harvest of the crop on the lands for which such refund is claimed.

RULE 16—ABANDONED USE OF WATER

Any person desiring to abandon any use of water shall deliver to the Secretary a written notice of such intention of abandonment and concurrently tender payment in full of all installments of water charge due at the date of delivery of notice.

RULE 17—WASTE OF WATER

Any water user, who in the opinion of the Manager, is wasting water (on roads, vacant land, or on land previously or presently irrigated) either wilfully, carelessly, negligently, or on account of defective private conduits, or who floods any portion of his land to an unreasonable depth or use

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an unreasonable amount of water in order to properly irrigate other portions; or whose land has been improperly checked for the economical use of water, or allows an unnecessary amount of water to escape from any tailgate, will be refused the use of water until such conditions are remedied.

The District reserves the right to refuse delivery of water when it appears to the satisfaction of the Manager that the proposed use, or method of use, will require such excessive quantities of water as will constitute waste.

RULE 18—SHORTAGE OF WATER

When, through lack of water, lack of conduit capacity, or for any other reason, it is not possible to deliver throughout the District or any portion thereof, the full supply of water required by the water users, such supply as can be delivered will be equitably prorated until such time as delivery of a full supply can be given.

RULE 19—COMPLAINTS

All complaints as to service, lack of water, or other unsatisfactory conditions, should be made immediately, in writing, addressed to the Manager of the District, at the District office.

RULE 20—ACCESS TO LAND

The authorized ditchtenders and other agents of the District shall have free access

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at all times to all lands irrigated from the canal system and to all conduits for the purpose of inspection, examination, measurements, surveys, or other necessary purposes of the District, with the right to install, maintain, control and regulate all meters or other measuring devices, gates, turnouts, or other structures necessary or proper for the measurement and distribution of water.

The District assumes no liability for damages to persons or property occasioned through defective conduits.

RULE 21—DAMAGE TO WORKS

Any person who shall permit any equipment, livestock, poultry, or waterfoul to damage or injure any works of the District, who shall damage, injure or destroy by burning or otherwise any such works, or who shall dump any rubbish therein or thereon, or erect fences on District rights-of-way, shall pay to the District upon demand all expenses incurred in the replacement of such property, or in the removal of such rubbish or fences.

RULE 22—ENFORCEMENT OF RULES

Failure or refusal of any landowner or water user to comply with these Rules or any interference by any such landowner, water user, his servants or employees, with the rights, duties or obligations of the District, or its employees, shall entitle the Distriict to discontinue the service of water

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to the lands of such owner or user until the landowner or water user shall furnish satisfactory proof to the Board of his intention to comply with these Rules or cease such interference, and shall remove any default existing at the time service of water is discontinued.

RULE 23—NON-LIABILITY OF DISTRICT

(a) The District will not be liable for any damage of any kind or nature resulting directly or indirectly from any private conduit, or the water flowing therein, or by reason of lack of capacity therein or for negligent, wasteful or other use or handling of water by the consumers therefrom.

(b) **Delivery of Water.** Most of the water furnished by the District flows through many miles of open ditches, and is subject to pollution, shortages, fluctuation in flow, and interruption in service. District employees are forbidden to make any agreements binding the District to serve an uninterrupted constant supply of water. All water furnished by the District will be on the basis of irrigation deliveries and every consumer putting the water to other uses does so at his own risk and by doing so assumes all liability for, and agrees to hold the District, and its officers, and employees free and harmless from liability and damages that may occur as a result of the defective water quality, shortages, fluctuation

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in flow, and interruptions in service.

District sells water as a commodity only and not as a guaranteed service and will not be liable for defective quality of water, shortage of water either temporary or permanent, or for failure to deliver such water.

(c) **PUMPING:** Pumping by consumers of District water is done at the consumers risk and the District assumes no liability for damages to pumping equipment or other damages as a result of turbulent water or shortages or excess of water, or other cause.

(d) **Conduits, etc.:** District assumes no liability for damages to persons or property occasioned through defective conduits, meters, or measuring devices.

PENALTY FOR UNAUTHORIZED TAKING OF WATER
PENAL CODE: Sec. 592

"Every person who shall, without authority of the owner or managing agent, and with intent to defraud, take water from any canal, ditch, flume or reservoir used for the purpose of holding or conveying water for manufacturing, agriculture, mining, irrigating or generation of power, or domestic uses or who shall without like authority raise, lower or otherwise disturb any gate or other apparatus thereof, used for the control of measurement of water; or who shall empty or place or cause to be emptied or placed into any such canal, ditch, flume or reservoir, any rubbish, filth or obstruction to the free flow of the water IS GUILTY OF A MISDEMEANOR."

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4.10.3 Potential Projects to Enhance Water Management Capabilities

A description of potential projects to enhance BWD water management capabilities is provided on the following pages.

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Attachment 4.10.3: Potential Projects to Enhance BWD Water Management Capabilities

Overview

A total of four potential projects to enhance water management by Butte Water District (BWD) were evaluated. These range from comprehensive system modernization to localized projects related to boundary outflow and safety spill measurement, removal of bottlenecks, and improving delivery service to customers using pressurized irrigation. For each project, reconnaissance level implementation costs have been estimated. It is anticipated that these projects would be implemented over time, subject to the availability of funding and project prioritization. Potential improvements are assembled into the following project categories:

1. System Modernization
2. Boundary Outflow and Primary Spill Measurement
3. Removal of Bottlenecks on the Sutter-Butte Main Canal
4. Alternatives for Improving Delivery Service to Pressurized Irrigation Systems

Summary of Cost Estimation

Reconnaissance level cost estimates were prepared for each improvement project as a basis for prioritization and funding of site improvements. The following summary of the cost estimation procedure applies to all projects described in this attachment.

Site inventories were completed with the help of district staff, and several sites were visited to provide information to develop conceptual designs to estimate material and labor quantities. Not all sites were surveyed in detail, and dimensions of structures and cross-sections were gathered only at a sample of locations. Many of the sites of a specific type (e.g. water level control) were similar in design and varied primarily in capacity. For this reason, conceptual designs were developed for each site type in several configurations and in a range of capacities as appropriate. The typical conceptual designs are listed in Table 1. Costs for the typical designs were developed based on estimates of required site components, quantities, and unit costs.

Table 1. Typical conceptual designs and the variations/configurations developed for purposes of cost estimation.

	Typical Design	Variations/Configurations
A	Acoustic Doppler velocimeter in lined section of channel	
B	Acoustic Doppler velocimeter in unlined section of channel	I. High capacity canal II. Mid-range capacity canal
C	New Precast Spill Box with 36" propeller meter at d/s end	I. 4 ft weir box II. 6 ft weir box
D	Precast headwall with new 36" undershot gate, piping and propeller meter at d/s end	
E	New Precast Spill Box with fixed, sharp-crest weir plate	I. 4 ft weir box II. 6 ft weir box
F	Locally automated combination weir	450, 250, 150, 75, 50, and 25 cfs capacity
G	Manually Adjusted Undershot Gates	Cost estimated on a per square foot of gate area basis
H	Automated Flow Control Gates	Cost estimated on a per square foot of gate area basis
I	SCADA hardware and related communication components	I. No add'l power source II. No add'l power source, w/ PLC III. W/ solar power system and PLC IV. W/ solar power system, pressure transducer and related components

Unit Costs

Unit costs for the various work items and materials were compiled from sources including published values, local suppliers, contractors and installers, and references from works previously completed by Davids Engineering and others. Standard unit prices were increased by 10% assuming prevailing labor rates will apply. Costs include material and equipment, installation labor, shipping, and tax (where applicable).

Cost types fall into three categories: Direct Costs, Indirect Costs, and Contingencies. Direct costs are associated with physical site improvements, while indirect costs represent other project costs such as engineering and design, environmental permitting, construction management, administration and legal, and overhead and are included as a percentage of the sum of extended costs plus the contingency. Contingency is applied to the subtotal of direct costs based on uncertainties present at this level of design and cost estimation and to account for unforeseen requirements.

Total indirect costs plus contingency vary by site type to account for differences in site complexities, construction effort, engineering and design requirements, the source of the unit cost information, and professional judgment. Mark-ups are summarized in Table 2.

All projects were assumed to be designed and constructed using competitive bidding processes. It is possible the site improvements could be implemented under a design-build scenario or by district forces at lesser costs than estimated in this analysis.

Table 2. Summary of range of percentage multipliers applied to cost estimate to account for indirect costs and contingencies.

Range of Percentages Applied to Total Direct Costs			
Engineering & Construction Management	10%	to	20%
Legal, Environmental and Administration	0%	to	20%
Total =	10%	to	40%
Percentage Applied to Total Site Cost			
Contingency	10%	to	20%

Quantities

Canal capacities were determined through consultation with district operators or estimated using Manning's equation for open channel flow using a combination of measured and assumed cross sectional geometry. For each canal, the top water width was measured at several locations using the point-to-point utility in Google Earth. Canal water depths were estimated based on spot field observations and by designating each canal a Main, Lateral, or sublateral canal. Average slopes along the canal lengths were estimated from Google Earth and USGS topographic maps. A Manning's roughness coefficient of 0.033 was used assuming excavated earthen canals, winding and sluggish with grass and some weeds, as defined in Te Chow (1959)[1]. Where available, calculated capacities were validated with measured capacities or typical peak diversions and globally adjusted as appropriate.

Quantities for larger heading and water level control structures were independently calculated and compared with conceptual structures designed for the Sutter Butte Regional Conveyance Study[2], conceptual structures in the WCWD Draft 20-Year Capital Improvements Plan, and with 60% design cost estimates[3] for the BWGWD Gray Lodge Wildlife Area Supply Project.

Site Specific Improvement costs

For each site, applicable designs and base costs for typical sites were used without modification, adjusted to reflect actual site conditions, or combined with components for other sites to create site specific improvement capital costs and annualized costs, as appropriate.

Annual Costs

Annual capital repayment was estimated for each item using an amortization rate of 5 percent and capital recovery factors calculated using the estimated expected life of each cost item. Total annual costs also include annual operations and maintenance (O&M) costs associated with the improvement. O&M costs were estimates as a percentage of the total extended cost of the item. The percentage ranged from 0 percent for items not requiring annual maintenance to 5 percent for electrical or mechanical components where more frequent O&M is necessary to ensure reliable operation and system longevity.

[1] Te Chow, Ven. 1959. Open Channel Hydraulics. The Blackburn Press, Caldwell, New Jersey, U.S.A.

[2] GEI Consultants, 2006. Regional Conveyance System Improvement Project – Final Report, May 2006. Completed for Sutter Extension Water District by Bookman-Edmonston, a division of GEI Consultants, Inc.

[3] Engineer's Opinion of Probable Construction Cost, 60% Design. October 2011. Prepared by Provost and Pritchard Consulting Engineers.

Project 1: System Modernization Project

Project Description

The system modernization project aligns with BWD's desire to develop and implement management strategies and tools to meet water management objectives, including water conservation at the district scale and improved delivery service to customers, especially those utilizing pressurized irrigation systems and weighing the option of utilizing surface water or groundwater.

System modernization is generally implemented to achieve one or more of the following goals:

1. Increase the efficiency of the distribution system to conserve water at the district scale,
2. Increase the level of service provided to growers and respond to changes in cropping or irrigation method,
3. Reduce potential risks to the safety of operations staff, and
4. Improve overall operability and management.

A phased, comprehensive modernization plan provides a road map for implementation that allows for improvements to occur over time at a pace that considers available funds and implements high priority improvements first to meet objectives in the most cost effective manner possible. The system modernization strategy developed for Butte Water District is a top-down strategy involving four phases with flow measurement as an overarching improvement. It is anticipated that the actual phasing of improvements to individual sites may differ from those described herein as informed by evaluation of opportunities, costs, and other considerations over time.

System modernization generally includes improvements to three site types: heading structures, upstream water level control structures, and spill structures. The objectives for each of these site types is described in Table 3. The specific improvements that would be completed under each of the four phases of modernization is described in additional detail below.

Table 3. System Modernization Objectives by Site Category.

Site Category	General Modernization Objective
Heading	• Replace old, aging and/or deteriorated structures and equipment, as needed. • Provide increased accuracy, repeatability, and consistency in downstream deliveries to district customers prevent farm runoff and tail end spills. • Improve ability for flow adjustments to prevent spill and enhance delivery service. • Increase safety of site for operators.
Upstream Water Level Control	• Replace old, aging and/or deteriorated structures and equipment, as needed. • Maintain constant upstream deliveries by reducing fluctuation in desired upstream water level over a range of canal flow rates. • Simplify operations by reducing the need to add or remove flashboards to maintain water levels across a range of flows. • Facilitate the ability to make frequent flow changes through the system, as needed. • Consolidate safety spills by eliminating intermediate safety spills, where practical. • Increase safety site for operators.
Spills	• Provide accurate and accessible measurement of spillage flow rate from the lateral as feedback loop on heading operation, general lateral operation, and District water accounting. • Increase safety of operating site.

Phase I System Modernization
The first phase would concentrate on primary inflow and operational outflow locations. These are generally the primary diversion locations or headings and main or primary canal end outflow points. The type and sophistication of improvement required to meet objectives varies by site, but the general objective is to provide improved control over the water that enters the district, as informed by improved information describing the timing and amount of water leaving the district. Readily accessible measurement of inflows and outflows has several benefits, including information for operational adjustments, data for water accounting and billing, and information to support further prioritization of improvements by quantifying potential benefits.

For BWD, the primary inflow points are the Sutter-Butte Main Canal at Thermalito Afterbay which is operated by the Joint Districts Board. The Joint Board coordinates releases with the California Department of Water Resources (DWR) operations staff for daily changes in inflow to the Sutter-Butte Canal. Downstream from the heading, the Looney Gates provide upstream water level control for the Biggs Extension canal which serves Biggs-West Gridley Water District and Richvale Irrigation District. BWD is the primary operator of the Sutter-Butte Canal below the Looney Gates. Flows into the Sutter-Butte Canal are measured just downstream of the release point by DWR, and the Joint Board operates an acoustic Doppler measurement site just downstream of the Looney Gates; although its accuracy is unverified and questionable. Fluctuations in the Biggs Extension Canal[4] can cause substantial fluctuations in flow passing to BWD (and SEWD). The Looney Gates are undersized for peak flows, thus limiting supplies to BWD, SEWD, and other downstream users. Construction of a higher capacity structure is recommended. Accurate flow measurement at primary inflow locations is also important to achieve modernization objectives because it would allow for more accurate and precise management of inflows to the distribution system.

Recommended improvements at the primary inflow location include relocation of the existing flow meter below the Looney Gates to a concrete lined section and stream gaging to calibrate measurements and verify accuracy. Remote monitoring of this site by the District manager (in addition to the Joint Board) and operators would provide improved operations and accounting.

Phase II System Modernization
The second phase of modernization would improve key control points along the main supply canal between the headings and outflows to increase conveyance efficiency. This would include main canal water level control structures and lateral headings. Existing control sites may be abandoned in some cases, re-configured, retrofitted, downsized, or retained. The addition of Phase II improvements would generally provide steadier delivery of water from the main canal to laterals and turnouts, simplify operations by adding automation and increased the ability to make flow changes, and concentrate primary routing of flow fluctuations along the main canal.

In BWD (as in most open canal systems) the Sutter-Butte canal contains primarily flashboard check structures that require adjustment whenever there is a flow change to avoid impacts to deliveries to laterals and turnouts along the canal. Without adjustment, undesirable water level fluctuations can impact these flows. In addition to impacting service, these fluctuations present challenges to water

[4] A modernization plan has been developed for the Joint Board as part of this Regional AWMP that would seek to help remedy water level fluctuation issues in the Sutter Butte and Biggs Extension canals.

accounting. Although many of the existing main canal structures are manual flashboard structures, BWD has initiated the modernization process by replacing the Thresher Weir with automated Langemann Gates and partially automating the Onstott Weir for upstream level control.

The modernization strategy for the Sutter-Butte Main canal is to provide new check structures to pass flow fluctuations downstream while maintaining upstream water levels across a range of flows with limited water level fluctuation. In order to function over a wide range of flows, new check structures would incorporate locally automated overshot gates. For purposes of the reconnaissance level cost estimates presented herein, several capacities of check structures were conceptually designed ranging from 1,000 cfs or more (Looney Gates and Holmes Weir) to 650 cfs at the Goat Weir. The use of adjustable overshot gates provides more flexible capacity with better performance when compared to fixed crest structures and would allow the upstream water depth to be minimized to reduce seepage during rice field dry-down periods (i.e., August and September) but when deliveries for orchard irrigation or waterfowl habitat are desired. Structures with adjustable crests also allow rapid passage of flow fluctuations with little to no change in upstream water level, thus maximizing capacity and limiting issues associated with limited freeboard.

Consolidation and routing of fluctuations along one primary route increases the likelihood that they can be used to meet downstream demand and allows for simplified monitoring of system operations to inform adjustments to diversions and upstream structures to reduce spillage. The ability to route flow fluctuations effectively is currently limited for two primary reasons. First, many main canal structures are unable to quickly pass fluctuations. As a result, the use of safety spills (such as Cox Spill) that provide temporary relief are required until adjustments can be made in the main canal. Secondly, canal capacity downstream of the Cox Weir is inadequate to convey the flow rate to meet total downstream demands. To make up for this, SEWD utilizes the Sunset Pumps to augment supplies which results in suboptimal electrical bills. Increasing the capacity of the canal below the Cox Weir has been explored and in addition to eliminating pumping requirements for SEWD would provide additional flexibility to BWD from a supply perspective but would also allow SEWD to temporarily back water out of laterals into the Sutter-Butte Canal without the risk of exceeding downstream capacity.

In addition to passing flow fluctuations downstream, new automated water level control structures would enable steadier deliveries to laterals and to growers off the main canal by providing steady upstream water levels; however, upstream water level control is only part of the solution to provide steady delivery rates. The modernization process recommends improvement of lateral headings along the main canal. These improvements would include new adjustable undershot gates and downstream flow measurement. In particular, remotely-controlled automated flow control gates are recommended at the Lateral 4, Lateral 6, and Chandon Lateral headings to allow frequent adjustment of these primary laterals. Manual gates are recommend for the other headings. The recommended measurement method for lateral headings depends on the frequency of use and lateral size. In general, smaller, less frequently used laterals would ideally be measured using propeller meters mounted to the discharge end of the heading pipe. Acoustic Doppler flow meters with continuous measurement capability are recommended for larger laterals.

The improvement of check structures and lateral headings described herein would establish the Sutter-Butte Canal as the primary spill route. Figure 1 provides an overview of all proposed improvement sites in BWD, including those in Phases III and VI described in later sections.

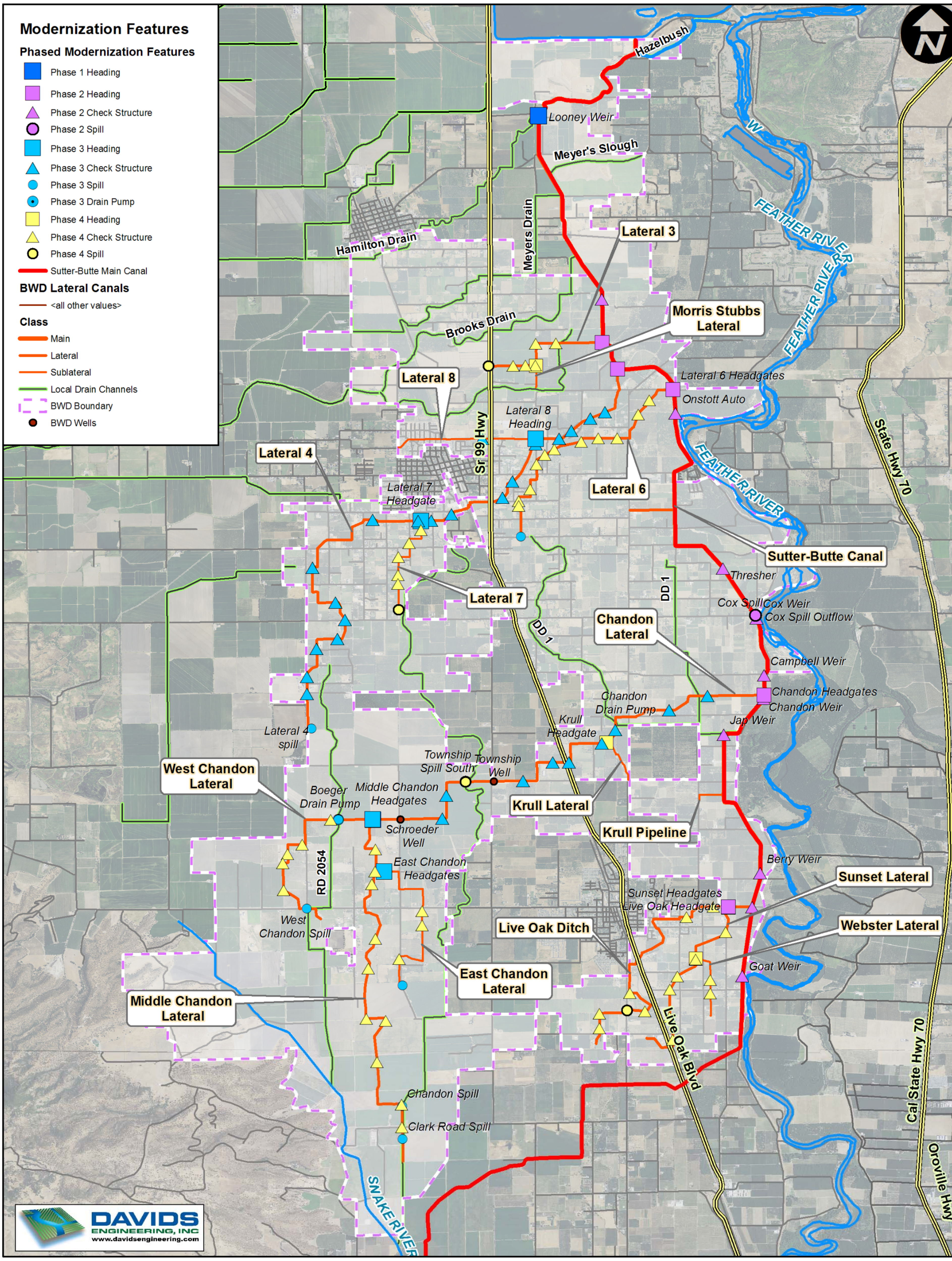

Figure 1. BWD System Modernization Phasing and Improvement Sites.

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Phase III System Modernization
The Phase II improvements to primary control points on the main canal would enable steadier flows to laterals and allow more flexible flow changes. To effectively extend these benefits to deliveries off of the laterals, Phase III would improve primary lateral control structures and primary end spills to improve control. The proposed improvements include replacement of all existing water level control structures on the Chandon Lateral and replacement of the West, Middle and East Chandon headgates. Additionally, Lateral 4 was identified as a candidate for improved routing of flow fluctuations and consolidation of safety spills to a single reregulation point at the Lateral 4 End Spill. Lateral 4 serves Lateral 8 and Lateral 7. With improved spill routing along Lateral 4, excesses in these sublaterals could be backed out to Lateral 4 and passed to the End Spill. Replacing existing check structures along Lateral 4 with long crested weirs would provide steady upstream water levels with no adjustment required. Additionally, because of the long weir length, a small change in head corresponds to a large change in flow enabling more rapid transfer of flow fluctuations down the system because the required change in upstream pond storage to pass the change is minimized. The Lateral 7 and 8 headgates would be improved to allow accurate and adjustable delivery. The existing end spill would be replaced with a new weir box and sharp crested weir structure to increase spill capacity (over existing) and provide accurate and consistent measurement for use by operators and for water accounting. All spills from Lateral 4 (and optimally from Lateral 7 and Lateral 8) would be discharged to the RD2054 drain channel for possible recovery at a new location on the Chandon Lateral at the existing Boeger Flume site.

A re-regulation point along the Chandon Lateral is an important component to system modernization, spill routing, and increasing the flexibility of service on all the Chandon Laterals. The objective of the improvement would be to essentially re-regulate the flow to the West Chandon and Middle Chandon Laterals using automated flow control gates. Water levels upstream of the new gates would be maintained constant in the event of surpluses or deficiencies by the Boeger weirs and a new variable frequency drive (VFD) controlled drain pump, respectively. Reconstruction of the canal upstream from the Boeger Flume to the Schroeder Well would create a level top pool which, aside from simplifying operations, would provide a limited amount of regulating storage. All excesses along the Chandon Lateral would be passed to this reregulation point and intermediate spill points (e.g. the Township Flume) would be re-operated to prevent spill. The Schroeder and Township Wells would also provide augmentation of supplies.

Phase IV System Modernization
The fourth phase would build on lateral heading flow control completed under Phase II and Phase III, and lateral water level control completed under Phase III by improving secondary control points along laterals and sublateral control points to inform and improve operations. Additionally, minor or secondary safety spills are prioritized for improvement, although some intermediate safety spills could likely not be needed and could be abandoned as check structures are improved to allow routing of flow fluctuations without causing substantial water level fluctuations, capacities are increased, and the controllability of flows at heading structures is increased. Objectives are to increase flexibility, consistency, and adequacy of supply to sublaterals; increased delivery steadiness and consistency; and concentrated routing of flow fluctuations to a measurement location providing operators with feedback to help determine the status of deliveries or the need for a change at the lateral heading to improve operations.

The fourth phase represents the final phase of system modernization to support spill reduction and possible diversion reduction, resulting in district-scale water conservation as well as increased levels of service. The final phase would complete additional improvements to: Lateral 3, Live Oak Lateral, Sunset Lateral, Webster Lateral, Krull Lateral, Lateral 7, West Chandon, Middle Chandon, and East Chandon. Additionally, Phase IV includes the improvement of six private ditch headings with new adjustable control and flow measurement. Private ditches improved include the Biggs Ditch, the Colony 3 Ditch, the Cushman Ditch, the Manzanita Lateral Heading, the Ownby Ditch Headgate, and the Krull Lateral.

Inventory of Existing Conditions

Existing conditions were characterized through consultation with district operations staff. For each site type, representative sites were selected for field inspection to obtain dimensions, coordinates, photos and operational features typical of the site type to aid in strategy development and cost estimation. Table 4 provides the site name, the site type, latitude, longitude, and a description of existing conditions for each site to be improved. Sites were assigned to one of the following categories: Inflow, Heading, Water Level Control, or Safety Spill. The sites identified may not be exhaustive.

Table 4. Inventory of Existing Conditions.

Site Name	Site Type	Latitude	Longitude	Description of Existing Conditions
Looney Weir	Water Level Control	39.436	-121.678	Two ~16ft wide AMIL gates installed in concrete structure. Approximate capacity is 900cfs.
Holmes Weir	Water Level Control	39.399	-121.665	Automated radial gate in the middle has 300 cfs capacity. 2 undershot bays on either side
Lateral 3 Headgate	Heading	39.390	-121.665	Concrete headwall with manually operated undershot gate
Lateral 4 Headgate	Heading	39.385	-121.662	Concrete structure with two 3.5-feet wide rectangular openings, 6-feet tall and 10ft long. Structure is in fair condition. Rectangular metal canal gates with operating wheels. 80 CFS capacity.
Lateral 6 Headgate	Heading	39.380	-121.651	25cfs capacity 1 36" and 1 24" diameter gate
Onstott Auto	Water Level Control	39.376	-121.651	Two automated vertical gates and four manually operated vertical gates
Thresher Weir	Water Level Control	39.344	-121.641	Two 16' Langemann gates
Cox Spill	Spill	39.335	-121.634	Automated overshot gate that maintains upstream water level or can be manually adjusted to spill.
Cox Weir	Water Level Control	39.334	-121.634	One hand-crank vertical gate and six flashboard bays.
Campbell Weir	Water Level Control	39.323	-121.633	Concrete structure with several flashboard bays
Chandon Headgate	Heading	39.319	-121.633	Four gates total in concrete headwall in fair condition. Two 4ftx6ft gates at center with a 24" and 36" undershot at sides.

Site Name	Site Type	Latitude	Longitude	Description of Existing Conditions
Chandon Weir	Water Level Control	39.318	-121.633	Concrete structure with several flashboard bays
Jap Weir	Water Level Control	39.311	-121.641	Concrete structure with several flashboard bays
Berry Weir	Water Level Control	39.283	-121.633	Concrete structure with several flashboard bays
Live Oak Headgate	Heading	39.276	-121.640	Structure in good condition
Sunset Headgate	Heading	39.276	-121.640	Structure in good condition
Pennington Weir	Water Level Control	39.276	-121.635	Eight flashboard bays
Goat Weir	Water Level Control	39.262	-121.637	Five flashboard bays
Lateral 4 Spill	Spill	39.312	-121.724	CMP weir box with 4' wide weir.20ft of 36" CMP provides drainage.
Lateral 6 Spill	Spill	39.351	-121.682	4' wide weir box upstream from Sheldon Road Crossing is regulated using boards. Spills travel through 12" RCP to East to DD1 drain
West Chandon Spill	Spill	39.276	-121.725	Two bay concrete weir structure. 4ft wide x 3.5ft deep openings. One for spill, one for continuation of lateral. 24" steel pipes convey water from structure to spill or lateral.
East Chandon Spill	Spill	39.260	-121.706	3' wide weir box and concrete headwall with 18" diameter outlet pipe that empties to drain.
Chandon Spill	Spill	39.236	-121.706	15" diameter sluice gate and concrete headwall. Downstream piping through embankment to adjacent drain ditch
Clark Road Spill	Spill	39.229	-121.706	4ft wide weir structure with concrete headwall side spills from canal to adjacent drain channel. 18" CMP pipeline provides conveyance and free falls into drain. Pipe appears to be flow restriction
Lateral 8 Headgate	Heading	39.371	-121.679	Concrete headwall with manually operated undershot gates
Lateral 4 Weirs	Water Level Control	Several Locations		Concrete structures with flashboards
Lateral 7 Headgate	Heading	39.354	-121.019	Concrete headwall with manually operated undershot gates
Boeger Flume	Spill	39.294	-121.719	Concrete flume structure with north and south 2ft-wide flash board bays that spill to RD2054. 15hp drain recovery pump. Existing check structure ~400ft downstream

Site Name	Site Type	Latitude	Longitude	Description of Existing Conditions
West Chandon Headgate	Heading	39.294	-121.712	Concrete headwall with manually operated undershot gates
Middle Chandon Headgate	Heading	39.294	-121.712	Concrete headwall with manually operated undershot gates
Chandon Lateral Weirs	Water Level Control	Several Locations		Concrete structures with flashboards
East Chandon Headgate	Heading	39.283	-121.709	Concrete headwall with manually operated undershot gates
Lateral 3 End Spill	Spill	39.385	-121.688	Concrete structure with flashboards
Lateral 7 End Spill	Spill	39.336	-121.706	Concrete weir box with flashboards. Piping carries spill to drain.
Live Oak End Spill	Spill	39.250	-121.666	Concrete weir box with flashboards spills directly to drain channel.
Sunset Lateral End Spill	Spill	39.252	-121.651	Concrete weir box with flashboards. Piping carries spill to drain.
Morris Stub Lateral Headgate	Heading	39.385	-121.679	24” sluice gate and 24” RCP at heading, 60” wide weir in Lateral 3
Township Flume and Spill	Spill	38.301	-121.693	North and South 4ft-wide slide gates that spill to RD2056. Top of gate acts as adjustable sill for water level control
Krull Headgate	Heading	39.309	-121.664	Concrete headwall with manually operated undershot gate
Webster Lateral Headgate	Heading	39.265	-121.646	Concrete headwall with manually operated undershot gates
Lateral 3 Weirs	Water Level Control	Several Locations		Concrete structures with flashboards
Lateral 7 Weirs	Water Level Control	Several Locations		Concrete structures with flashboards
Lateral 6 Weirs	Water Level Control	Several Locations		Concrete structures with flashboards
West Chandon Weirs	Water Level Control	Several Locations		Concrete structures with flashboards
Middle Chandon Weirs	Water Level Control	Several Locations		Concrete structures with flashboards

Site Name	Site Type	Latitude	Longitude	Description of Existing Conditions
East Chandon Weirs	Water Level Control	Several Locations		Concrete structures with flashboards
Sunset Weirs	Water Level Control	Several Locations		Concrete structures with flashboards
Live Oak Weirs	Water Level Control	Several Locations		Concrete structures with flashboards
Webster Weirs	Water Level Control	Several Locations		Concrete structures with flashboards

System Modernization Physical and Operational Improvements

Level 1 and 2 Improvements

For each site, improvement is split into two levels, Level 1 and Level 2. Level 1 improvements typically include fundamental infrastructure and measurement enhancements that are manually operated or read, or locally automated, and designed as SCADA-Ready[5]. These improvements include, but not limited to new, manually adjustable heading gates; long crested weirs; locally automated overshot gates; and measurement devices such as weirs, acoustic Doppler flow meters, and propeller meters. Level 2 improvements build upon Level 1 improvements by automating certain additional features, adding electronic sensors, installing on-site digital display of flow rate or other parameters, or adding remote monitoring or control through a Supervisory Control and Data Acquisition System (SCADA). Level 1 improvements are stand-alone, while Level 2 improvements generally require Level 1 to be completed prior to or at the same time. The progression from level 1 to level 2 improvements provides the flexibility to complete Level 1 (which has significant benefits on its own) while assessing the benefits of SCADA, further prioritizing sites, establishing a SCADA base station, and gradually implementing potentially more complex and technically intricate remote control sites.

Although Level 2 is not universally required to be completed to obtain significant benefits, several sites would substantially benefit. Two examples of this are:

1. Remotely located end spill sites not frequently visited by operators. Remote monitoring would reduce travel time potentially enabling additional flow changes, as needed.
2. Automated flow control gates at headings with substantial upstream water level fluctuations; however, assuming water level control structures are installed, the flow control device could have little additional benefit until remote control is added to allow for flow adjustments.

In some cases, there could be capital cost savings by completing Level 1 and Level 2 improvements at the same time.

[5] "SCADA-Ready" describes a package of hardware and/or software that communicates and operates locally but has been specifically designed and installed to readily accept a data transmission and receiving device (e.g. radio, cellular modem, etc.) and to provide remote communication with an established base station and SCADA human machine interface (HMI).

Table 5 provides a description of the improvements proposed for each site, the objective of the improvements and estimated Phase I and Phase II improvement costs. For each site and level of improvements, upfront capital costs and annualized capital, operations, and maintenance costs are provided. All costs are subject to revision following refinement of site improvements as informed by more detailed review and design.

Table 5. Site Improvement Matrix.

Site Name	Site Type	Description of Operational Objective with Improvements	Level 1 Modernization and Enhancement	Capital Cost ($)	Annual Cost ($/yr)	Level 2 Modernization and Enhancement	Capital Cost ($)	Annual Cost ($/yr)
SCADA Office Base Station		Allows remote monitoring of measured parameters at SCADA equipped sites. Also allows remote control and adjustment of set points at automated water level or flow control sites. Provides for storage of data and interface for developing comprehensive status reports, usage statistics, and monitoring information for improved water management, accounting and reporting.	Level 1 Modernization and Enhancement does not include SCADA at sites; therefore, base station is not required.	$0	$0	Furnish and install one desktop personal computer, including: processor, monitor, keyboard, mouse, drivers, USB, RS232, Ethernet, communication ports, cables, adapters, modems, printer, operating system software and HMI software. Base station spread spectrum radio, mast, and antenna for communication with remote sites. Five hardened laptops and vehicle mounts for operator/in-field use. Vehicle-mounted radios and antennas for remote communications and monitoring of sites.	$138,063	$17,039
Spare Equipment		Minimize down time associated with simple equipment maintenance or malfunctions and/or procurement of site or system specific hardware.	Small inventory of site and system specific equipment that is critical for proper operation of improvements.	$23,692	$2,913		$0	$0
Phase 1 Modernization - Improvement of Primary Inflow Locations and Primary Operational Outflow Locations								
Looney Weir	Water Level Control	Provide upstream level control over full range of operational flow rates in Sutter Butte Main Canal to ensure steady deliveries to RD833 Drain and Greenhouse Gates.	See Joint Board Improvement Description. Remove existing AMIL gates and construct new structure with minimum capacity of 1,000 cfs.	$493,947	$27,057	Add upstream water level sensor and integrate with SCADA system to allow monitoring of water levels	$7,400	$700
Sutter-Butte Main Canal Inflow	Flow Measurement	Provide Joint-Board operators, BWD managers, and BWD canal operators with accurate inflow to the Sutter-Butte Main Canal for improved water allocation, accounting and general management.	Construct concrete lined control section at location of existing meter d/s of Looney Weir. Perform velocity index calibration of existing meter and install walkway over sensor for verification purposes. Replace meter as necessary.	$55,400	$5,300	Upgrade and reinstall existing solar power site, flow display and communication hardware and integrate with SCADA system to allow remote monitoring of flow rate.	$5,900	$600
Phase 2 Modernization - Improvement of Main Canal Primary Control Points								
Holmes Weir	Water Level Control	Provide upstream level control over full range of operational flow rates in Sutter Butte Main Canal to ensure steady deliveries to upstream lateral headings and deliveries, and pass fluctuations downstream.	Replace existing structure with fully automated upstream water level control gate. New structure capacity is 1,000 cfs.	$1,218,889	$66,767	Integrate with SCADA system to allow remote manual adjustment of set points and monitoring of water levels and gate function.	$7,400	$700
Lateral 3 Headgate	Heading	Provide accurate, repeatable and consistent flow to supply deliveries downstream of the lateral heading.	Install ADVM downstream from gates in straight section of channel. Perform velocity index calibration. Install digital display of flow rate at heading gates to inform adjustments. Flow measurement site will be SCADA-Ready.	$26,400	$2,900	Due to deteriorating concrete, replace existing concrete structure with new structure and new undershot gates. Install communication hardware and integrate with SCADA system to allow remote monitoring.	$23,300	$1,800
Lateral 4 Headgate	Heading		Install ADVM downstream from gates in straight section of channel. Perform velocity index calibration. Install digital display of flow rate at heading gates to inform adjustments. Flow measurement site will be SCADA-Ready.	$26,400	$2,900	Due to deteriorating concrete, replace existing concrete structure with new structure and new automated flow control gates. Install communication hardware and integrate with SCADA system to allow remote monitoring and control of gate function and set points.	$106,700	$7,800
Lateral 6 Headgate	Heading		Install ADVM downstream from gates in straight section of channel. Perform velocity index calibration. Install digital display of flow rate at heading gates to inform adjustments.	$26,400	$2,900		$106,700	$7,800
Onstott Auto	Water Level Control	Provide upstream level control over full range of operational flow rates in Sutter Butte Main Canal to ensure steady deliveries to upstream lateral headings and deliveries, and pass fluctuations downstream.	Replace existing structure with fully automated upstream water level control gate. New structure capacity is 950cfs.	$1,208,236	$66,183	Integrate with SCADA system to allow remote manual adjustment of set points and monitoring of water levels and gate function.	$7,400	$700

Site Name	Site Type	Description of Operational Objective with Improvements	Level 1 Modernization and Enhancement	Capital Cost ($)	Annual Cost ($/yr)	Level 2 Modernization and Enhancement	Capital Cost ($)	Annual Cost ($/yr)
Thresher Weir	Water Level Control		Integrate existing automated upstream water level control structures with the SCADA system to allow remote monitoring and remote manual adjustment of gate set points.	$7,400	$700	None	$0	$0
Cox Spill	Spill	Provide site for operational spillage to return to the Feather River. Enable remote monitoring of spillage and gate operation to improvement management.	Integrate existing measurement site with SCADA system.	$11,800	$1,200	None	$0	$0
Cox Weir	Water Level Control	Provide upstream level control over full range of operational flow rates in Sutter Butte Main Canal to ensure steady deliveries to upstream lateral headings and deliveries, and pass fluctuations downstream.	Replace existing structure with fully automated upstream water level control gate. New structure to have a maximum capacity of at least 865 cfs.	$997,297	$54,629	Integrate with SCADA system to allow remote manual adjustment of set points and monitoring of water levels and gate function.	$7,400	$700
Campbell Weir	Water Level Control		Replace existing structure with fully automated upstream water level control gate. New structure to have a maximum capacity of at least 825 cfs.	$908,043	$49,740	Integrate with SCADA system to allow remote manual adjustment of set points and monitoring of water levels and gate function.	$7,400	$700
Chandon Headgate	Heading	Provide accurate, repeatable and consistent flow to supply deliveries downstream of the lateral heading.	Install ADVM downstream from gates in straight section of channel. Perform velocity index calibration. Install digital display of flow rate at heading gates to inform adjustments.	$26,400	$2,900	Replace existing concrete structure with new, higher capacity concrete structure. Add automated gate with sufficient capacity for daily adjustments and manual gate for typical base flow. Install solar power system, digital display, PLC and integrate with SCADA system to allow remote manual adjustment of set points and monitoring of flow rate, water levels and gate function.	$189,740	$13,560
Chandon Weir	Water Level Control	Provide upstream level control over full range of operational flow rates in Sutter Butte Main Canal to ensure steady deliveries to upstream lateral headings and deliveries, and pass fluctuations downstream.	Replace existing structure with fully automated upstream water level control gate. New structure to have a maximum capacity of at least 800 cfs.	$899,687	$49,282	Integrate with SCADA system to allow remote manual adjustment of set points and monitoring of water levels and gate function.	$7,400	$700
Jap Weir	Water Level Control		Replace existing structure with fully automated upstream water level control gate. New structure to have a maximum capacity of at least 765 cfs.	$797,122	$43,664	Integrate with SCADA system to allow remote manual adjustment of set points and monitoring of water levels and gate function.	$7,400	$700
Berry Weir	Water Level Control		Replace existing structure with fully automated upstream water level control gate. New structure to have a maximum capacity of at least 725 cfs.	$797,122	$43,664	Integrate with SCADA system to allow remote manual adjustment of set points and monitoring of water levels and gate function.	$7,400	$700
Live Oak Headgate	Heading	Provide accurate, repeatable and consistent flow to supply deliveries downstream of the lateral heading.	Install ADVM downstream from gates in straight section of channel. Perform velocity index calibration. Install digital display of flow rate at heading gates to inform adjustments. Site will be SCADA-Ready	$26,400	$2,900	Install communication hardware and integrate with SCADA system to allow remote monitoring.	$5,900	$600
Sunset Headgate	Heading		Install ADVM downstream from gates in straight section of channel. Perform velocity index calibration. Install digital display of flow rate at heading gates to inform adjustments.	$26,400	$2,900		$5,900	$600
Pennington Weir	Water Level Control	Provide upstream level control over full range of operational flow rates in Sutter Butte Main Canal to ensure steady deliveries to upstream lateral headings and deliveries, and pass fluctuations downstream.	Replace existing structure with fully automated upstream water level control gate. New structure to have a maximum capacity of at least 685 cfs.	$797,122	$43,664	Integrate with SCADA system to allow remote manual adjustment of set points and monitoring of water levels and gate function.	$7,400	$700

Site Name	Site Type	Description of Operational Objective with Improvements	Level 1 Modernization and Enhancement	Capital Cost ($)	Annual Cost ($/yr)	Level 2 Modernization and Enhancement	Capital Cost ($)	Annual Cost ($/yr)
Goat Weir	Water Level Control		Replace existing structure with fully automated upstream water level control gate. Integrate with SCADA system to allow remote manual adjustment of set points and monitoring of water levels and gate function. New structure to have a maximum capacity of at least 650 cfs.	$797,122	$43,664	Integrate with SCADA system to allow remote manual adjustment of set points and monitoring of water levels and gate function.	$7,400	$700
Phase 3 Modernization - Improvement of Lateral Primary Control Points and Spill Routing								
Lateral 4 Spill	Spill	Provide accurate and accessible measurement of spillage flow rate from the lateral as feedback loop on heading operation, general lateral operation, District water accounting and to inform operation of Boeger re regulation point.	Replace weir box with new. Install sharp crested weir plate and mount custom staff gage calibrated to report spill flow rate based on the depth of water above the weir crest.	$8,700	$700	Install pressure transducer in new stilling well upstream of spill box to measure head on weir. Perform calibration of weir. Install communication hardware and integrate with SCADA system to allow remote monitoring.	$15,400	$1,500
Lateral 6 Spill	Spill	Provide accurate and accessible measurement of spillage flow rate from the lateral as feedback loop on heading operation, general lateral operation, and District water accounting.	Install weir boards in existing spill box to control spill rate. Install weir box on downstream end of existing pipe and install open channel propeller meter. Install trash rack at inlet. Site will be SCADA-Ready	$19,100	$1,700	Install communication hardware and integrate with SCADA system to allow remote monitoring.	$11,800	$1,200
West Chandon Spill	Spill		Replace weir box with new. Install sharp crested weir plate and mount custom staff gage calibrated to report spill flow rate based on the depth of water above the weir crest.	$8,700	$700	Install pressure transducer in new stilling well upstream of spill box to measure head on weir. Perform calibration of weir. Install communication hardware and integrate with SCADA system to allow remote monitoring.	$15,400	$1,500
East Chandon Spill	Spill			$8,700	$700		$15,400	$1,500
Chandon Spill	Spill		Modify operations to pass excesses to Clark Road Spill. Operate Chandon Spill on emergency basis only.	$0	$0	None	$0	$0
Clark Road Spill	Spill		Remove existing concrete weir box and CMP. Install longer overpour weir with fixed, sharp crest, install drain gate and larger discharge piping to ensure free flow over weir. Install custom staff gage calibrated to report spill flow rate based on the depth of water above the weir crest.	$8,700	$700	Install pressure transducer in new stilling well upstream of spill box to measure head on weir. Perform calibration of weir. Install communication hardware and integrate with SCADA system to allow remote monitoring.	$15,400	$1,500
Lateral 8 Headgate	Heading	Provide accurate, repeatable and consistent flow to supply deliveries downstream of the lateral heading.	Install weir box on downstream end of existing pipe and install open channel propeller meter. Install trash rack at inlet. Replace heading gate as necessary to provide adjustable and reliable control. Site will be SCADA-Ready.	$26,400	$2,400	Replace existing gate and structure with new automated flow control gate. Install communication hardware and integrate with SCADA system to allow remote monitoring and control of gate function and set points.	$44,800	$3,200
Lateral 4 Weirs	Water Level Control	Maintain upstream water level for constant upstream deliveries and to route any flow fluctuations down Lateral 4 to the end spill for potential recapture at the proposed Boeger Flume re Regulation site.	Replace all water level control structures in Lateral 4 from the heading to the spill with LCWs. Total of 18 structures.	$833,800	$53,200	None	$0	$0
Lateral 7 Headgate	Heading	Provide accurate, repeatable and consistent flow to supply deliveries downstream of the lateral heading.	Install weir box on downstream end of existing pipe and install open channel propeller meter. Install trash rack at inlet. Replace heading gate as necessary to provide adjustable and reliable control. Site will be SCADA-Ready.	$26,400	$2,400	Replace existing gate and structure with new automated flow control gate. Install communication hardware and integrate with SCADA system to allow remote monitoring and control of gate function and set points.	$44,800	$3,200

Site Name	Site Type	Description of Operational Objective with Improvements	Level 1 Modernization and Enhancement	Capital Cost ($)	Annual Cost ($/yr)	Level 2 Modernization and Enhancement	Capital Cost ($)	Annual Cost ($/yr)
Boeger Flume Re Regulation	Flow Control	Re regulate flow in the Chandon Lateral upstream of the West and Middle Chandon Headgates to provide constant flowrate to downstream deliveries. Excesses in supply are spilled instead of being passed downstream and deficiencies are met by extracting drain water from the 2054 Drain.	Replace existing pump with new variable speed drive unit with controls to maintain water level in Chandon Lateral. Relocate heading of West Chandon to just downstream from flume with undershot gates and raise banks upstream from flume approximately 0.7miles to the Schroeder Well to create level-top pool. Install flap gates in existing flashboard bays in walls of flume to maintain water level and pass excesses to drain.	$232,240	$16,781	Automate flow control gates and new heading of West Chandon to allow remote control. Install solar power system, PLC, communication hardware and integrate with SCADA system to allow remote monitoring of levels, flow rates, and pump operation.	$57,700	$3,391
West Chandon Headgate	Heading	Provide accurate, repeatable and consistent flow to supply deliveries downstream of the lateral heading.	See description for Boeger Flume Re Regulation. New flow control structure for West Chandon lateral will be just downstream of Boeger Flume and consist of a new concrete headwall with two undershot gates for flow control. Add ADVM downstream and digital flow display at gates. Site will be SCADA-Ready.	$0	$0	Automate flow control gates and new heading of West Chandon to allow remote control. Install solar power system, PLC, communication hardware and integrate with SCADA system to allow remote monitoring of levels, flow rates, and pump operation.	$0	$0
Middle Chandon Headgate	Heading		See Boeger Flume re regulation improvement description. Install new heading structure with adjustable control. Install ADVM downstream of gates to measure flow. Site will be SCADA-Ready.	$0	$0	None	$0	$0
Chandon Lateral Weirs	Water Level Control	Maintain upstream water level for constant upstream deliveries while quickly routing flow changes down the lateral to meet downstream deliveries, or passing excesses to the proposed re regulation point at Boeger Flume.	Replace all water level control structures in Chandon Lateral from the heading to Boeger spill with combination water level control structures. Total of nine structures	$1,463,900	$108,100	None	$0	$0
East Chandon Headgate	Heading	Provide accurate, repeatable and consistent flow to supply deliveries downstream of the lateral heading.	Install long crested weir at split of Middle Chandon and East Chandon. Retain existing undershot gates and install measurement downstream from East Chandon gates with digital flow rate display at heading gates.	$79,500	$6,300	Replace existing gate and structure with new automated flow control gate. Install communication hardware and integrate with SCADA system to allow remote monitoring and control of gate function and set points.	$5,900	$600
East Chandon Spill	Spill	No measurement. 3' wide weir box and concrete headwall with 18" diameter outlet pipe that empties to drain. Turnout immediately upstream	Install weir box on downstream end of existing pipe and install open channel propeller meter. Install trash rack at inlet. Site will be SCADA-Ready	$19,100	$1,700	Add communication hardware to measurement site and integrate with SCADA system to provide real-time monitoring of flow rate and water level.	$11,800	$1,200
Phase 4 Modernization - Improvement of Lateral Secondary Points, Sublateral Control Points and Secondary Spill Points								
Lateral 3 End Spill	Spill	Provide accurate and accessible measurement of spillage flow rate from the lateral as feedback loop on heading operation, general lateral operation, and District water accounting.	Replace weir box with new concrete structure. Install sharp crested weir plate and mount custom staff gage calibrated to report spill flow rate based on the depth of water above the weir crest.	$8,700	$700	Install pressure transducer in new stilling well upstream of spill box to measure head on weir. Perform calibration of weir. Install communication hardware and integrate with SCADA system to allow remote monitoring.	$15,400	$1,500
Lateral 7 End Spill	Spill			$8,700	$700		$15,400	$1,500
Live Oak End Spill	Spill			$8,700	$700		$15,400	$1,500
Sunset Lateral End Spill	Spill			$8,700	$700		$15,400	$1,500
Morris Stub Lateral Headgate	Heading	Provide accurate, repeatable and consistent flow to Morris Stub Lateral if needed to supply deliveries.	Morris Stub Lateral is currently used as a drain channel due to the absence of deliveries. No improvement is recommended at this time.	$0	$0	None	$0	$0

Site Name	Site Type	Description of Operational Objective with Improvements	Level 1 Modernization and Enhancement	Capital Cost ($)	Annual Cost ($/yr)	Level 2 Modernization and Enhancement	Capital Cost ($)	Annual Cost ($/yr)
Township Flume and Spill	Spill	Convey water across Morrison Slough and enable accurate and repeatable deliveries to the Slough for downstream deliveries when needed.	Discontinue use of existing slide spill gates, but retain for emergency purposes. All spills are routed to proposed Boeger re regulation site. Install new sluice gate outlet with inline propeller meter.	$19,100	$1,700	Install solar power system, communication hardware and integrate flow measurement site with SCADA system to allow remote monitoring of flow being delivered to drain.	$11,800	$1,200
Krull Headgate	Heading	Provide accurate, repeatable and consistent flow to supply deliveries downstream of the lateral heading.	Replace check structure in Chandon Lateral with LCW. Install new head gates with flow measurement.	$26,400	$2,400	Install communication hardware and integrate with SCADA system to allow remote monitoring.	$11,800	$1,200
Webster Lateral Headgate	Heading		Replace gates in Sunset Lateral with long crested weir, install measurement downstream from existing Webster lateral heading.	$26,400	$2,400	Install communication hardware and integrate with SCADA system to allow remote monitoring.	$11,800	$1,200
Lateral 3 Weirs	Water Level Control	Maintain constant upstream deliveries by maintaining the desired upstream water level in the supply canal over a range of canal flow rates. Simplify operations by reducing the need to add or remove flashboards, and increase the rate at which flow changes can be passed through the system	Replace five existing check structures with LCWs.	$111,000	$7,000	None	$0	$0
Lateral 7 Weirs			Replace five existing check structures with LCWs.	$111,000	$7,000	None	$0	$0
Lateral 6 Weirs			Replace eleven existing check structures with LCWs.	$244,200	$15,400	None	$0	$0
West Chandon Weirs			Replace five existing check structures with LCWs.	$111,000	$7,000	None	$0	$0
Middle Chandon Weirs			Replace ten existing check structures with LCWs.	$409,000	$26,000	None	$0	$0
East Chandon Weirs			Replace three existing check structures with LCWs.	$66,600	$4,200	None	$0	$0
Sunset Weirs			Replace six existing check structures with LCWs.	$133,200	$8,400	None	$0	$0
Live Oak Weirs			Replace six existing check structures with LCWs.	$133,200	$8,400	None	$0	$0
Webster Weirs			Replace two existing check structures with LCWs.	$44,400	$2,800	None	$0	$0
Biggs Ditch	Private Ditch	Provide accurate, repeatable and consistent flow to private ditch to supply deliveries downstream and to improve water accounting.	Install weir box on downstream end of existing pipe at heading and install open channel propeller meter. Replace heading gate as necessary to provide adjustable and reliable control. Site will be SCADA-Ready.	$19,100	$1,700	Install communication hardware and integrate with SCADA system to allow remote monitoring.	$11,800	$1,200
Colony 3	Private Ditch			$19,100	$1,700		$11,800	$1,200
Cushman Ditch	Private Ditch			$19,100	$1,700		$11,800	$1,200
Manzanita Lateral Heading	Private Ditch			$19,100	$1,700		$11,800	$1,200
Ownby Ditch Headgate	Private Ditch			$19,100	$1,700		$11,800	$1,200
Krull Lateral	Private Ditch			$19,100	$1,700		$11,800	$1,200

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System Modernization Costs

The total combined cost (all phases, Level 1 and Level 2) of system modernization is estimated to be approximately $14,207,000, with annualized estimated costs of $872,000. Individual costs by modernization phase range from a low of $563,000 to a high of $9,103,000 for Phase 1 and Phase 2, respectively. Costs are further summarized in Table 6. Additionally, the costs of a SCADA base station and mobile operator terminals that would form the backbone of the District SCADA system have been estimated, along with the cost of spare equipment to be kept on hand to repair or replace individual site components due to theft, vandalism, or other failure. The cost of the SCADA base station may be drastically reduced, or eliminated, if the district is able to 'piggy-back' on to and expand the existing SCADA network current owned and operated by the Joint Water Districts Board.

Table 6. Summary of Estimated Capital and Annualized Costs.

	Level 1		Level 2	
Modernization Phase	**Capital Cost ($)**	**Annual Cost ($/yr)**	**Capital Cost ($)**	**Annual Cost ($/yr)**
Phase I - Improvement of Primary Inflow Locations and Primary Operational Outflow Locations	$549,347	$32,357	$13,300	$1,300
Phase II - Improvement of Main Canal Primary Control Points	$8,598,241	$480,555	$504,840	$38,460
Phase III - Improvement of Lateral Primary Control Points and Spill Routing	$2,735,240	$195,381	$238,400	$18,791
Phase IV - Improvement of Lateral Secondary Points, Sublateral Control Points and Secondary Spill Points	$1,470,300	$95,500	$97,000	$9,600
Total Cost =	$13,353,128	$803,793	$853,540	$68,151
SCADA Office Base Station	-	-	$138,063	$17,039
Spare Parts	$23,692	$2,913		-

Potential Benefits

The system modernization plan described herein represents comprehensive improvements to the district's distribution system, adding several automated control structures, improved measurement, new heading structures, re-regulation points, and SCADA. Flow paths targeted under of the system modernization project are:

- Operational spillage,
- Tailwater,
- Drainage Outflows, and
- Diversions

Improvements would allow reduced operational spillage and reduced deliveries due to increased delivery efficiency, which could reduce on-farm tailwater and, in some cases, deep percolation. Reduced deliveries result in reduced diversions, which results in corresponding reductions in spillage and drainage outflows. Available water not diverted remains in storage and could potentially meet local, regional, or statewide water management objectives.

Through implementation of the system modernization program (Phases I - IV and Levels 1 and 2), it is estimated that approximately 20 to 50 percent[6] of existing operational spillage could be conserved annually, or between approximately 2,000 and 5,000 af per year. This conserved water could be used to:

- Increase local water supply,
- Increase local water delivery flexibility,
- Increase in-stream flow, and/or
- Improve water quality

Each phase provides varying levels of anticipated benefit with the first two phases likely seeing greater benefit than the third and fourth due to the greater number of sites improved, establishment of primary spill routing, and improvement of control structures that are located higher in the system (i.e. have control over a larger proportion of the total water diverted). The marginal estimated range of percent reduction in spillage and boundary outflow achieved by completing phases is described below:

1. Phase I: 1 to 2 percent reduction; 100 to 200 af of the targeted flow path
2. Phase II: 12 to 25 percent reduction; 1,200 to 2,500 af of the targeted flow path
3. Phase III: 5 to 15 percent reduction; 500 to 1,500 af of the targeted flow path
4. Phase IV: 2 to 8 percent reduction; 200 to 800 af of the targeted flowpath

Net Benefit Analysis

The district is currently implementing associated EWMPs at locally cost-effective levels. BWD has not used its full allocation in recent years, and thus would not achieve cost savings through additional conservation. The estimated implementation cost per unit of water conserved is presented in Table 7. In the table, annualized costs of the SCADA base station are distributed across phases based on the relative magnitude of annualized costs for each phase. Currently, the unit cost of conservation exceeds the potential monetary savings. As a result, further implementation of the system modernization project is not locally cost effective at this time. In the future, it is anticipated that the costs and estimated benefits of this improvement project will be evaluated as additional information becomes available.

[6] Potential spillage reduction was based in part on information from the technical memorandum "Spillage Reduction- Monitoring and Verification" published by the Agricultural Water Management Council and partly on experience with local conditions and judgment. Reductions in tailwater can also be assumed to some degree given the improved delivery steadiness, flow measurement, and control that this project enables.

Table 7. Estimated Implementation Cost per Unit of Water Conserved.

Modernization Phase	Annual Cost, Levels 1 and 2 ($/yr)	Conserved Water Range (af/yr)			Conservation Cost ($/af)		
Phase I - Improvement of Primary Inflow Locations and Primary Operational Outflow Locations	$34,427	100	to	200	$172	to	$344
Phase II - Improvement of Main Canal Primary Control Points	$530,891	1,200	to	2,500	$212	to	$442
Phase III - Improvement of Lateral Primary Control Points and Spill Routing	$219,073	500	to	1,500	$146	to	$438
Phase IV - Improvement of Lateral Secondary Points, Sublateral Control Points and Secondary Spill Points	$107,505	200	to	800	$134	to	$538
Totals	$891,896	2,000	to	5,000	$178	to	$446

Project 2: Boundary Outflow and Primary Spill Measurement and Drain Water Recovery Project

Project Description

Two improvement packages are described in this section: Boundary Flow and Primary Spill Measurement, and Drain Water Recovery. Both of these projects have similar objectives, as described in Table 8. The project summaries provided in this attachment include an inventory of existing or potential sites that fall into one of the classifications described in Table 9.

For each site, conceptual designs were developed to meet the objectives. A total of seven boundary outflow locations, five boundary inflow sites, and 17 internal spill sites, two internal inflow sites, and two drain water recovery sites were identified for improvement under these two improvement packages. The selected sites (shown in Figure 2) were identified as high priority through consultation with district personnel or identified has likely high use sites based on their position in the distribution system, such as at the end of main canals or primary laterals. Several additional spill sites were identified but not included in this improvement package because of their perceived low volume or infrequent use. Recommended improvement sites are subject to revision following refinement of prioritization criteria and more detailed review and analysis.

Table 8. Objectives of Boundary Outflow and Primary Spill Measurement and Drain Water Recovery Projects.

Objective	Boundary Flow and Primary Spill Measurement	Drain Water Recovery
Improve Water Use Efficiency	Measurement of operational spillage and drainage flows can be used to make better informed system adjustments that can lead to reduced spillage and possibly a reduction in total demands. Reduced spillage and reduced tailwater can lead to reduced diversions.	Reuse of operational spillage and tailwater results in decreased required diversions. Available water not diverted remains in storage and could potentially be availableto meet unmet demands or for transfer.
Develop Water Use Data	Measurement of boundary outflows and primary spillage provides the data necessary to quantify surface water leaving district, better define unmeasured flows (such as deep percolation), determine areas of high loss, characterize operational efficiencies, and aid in prioritization of improvements.	
Support Reporting	Measurement of spillage, boundary flows and recovered drainwater provides information relating to water supply, water use, water quality, environmental benefits, etc. Measurement also supports the district in responding to potential inquiries from landowners regarding water supply, water use, and historical trends.	
Increase Operational Efficiency	Measurement of spillage enables operators to make corresponding adjustments at lateral headings or at the diversion to reduce spillage or total diversions. Measurement provides early detection of end canal conditions (high or low) that may be impacting delivery service.	Recovering drain water enables operators to meet demands more quickly and flexibly. Measurement will inform adjustments, maximizing drainwater extraction, minimizing diversions and minimizing spillage.

Table 9. Site Type Classifications.

Site Type Classification	Description	Improvement Package
Boundary Inflow	Flows entering the District boundaries and providing the availability of increased supply.	Boundary Flow and Primary Spill Measurement
Boundary Outflow	Flows leaving the District boundaries and representing excess inflows, intentional releases to satisfy obligations to meet out-of-District demands, or water management issues.	Boundary Flow and Primary Spill Measurement
Internal Outflow	Flows intentionally discharged from District canals to drainage channels for downstream delivery or possible recapture (e.g. deliveries to Secondary).	Boundary Flow and Primary Spill Measurement
Internal Inflow	Additional supply entering the District from within its boundaries. (e.g. groundwater wells).	Boundary Flow and Primary Spill Measurement
Internal Spill	Excesses in supply canals that are discharged to drain channels through safety spill structures.	Boundary Flow and Primary Spill Measurement
Drain Water Recovery (Pump)	Recapture of drain water via pump as it passes through the District. Recaptured water may be spillage or tailwater from neighboring Districts, or from internal sources.	Drain Water Recovery

Recommended measurement devices for the boundary and spill flows vary by site type, site conditions and existing infrastructure or proposed infrastructure. Additionally, the intensity of use (rate and duration) relative to other sites, and the importance of the site to meeting the objectives also factor into the selection of measurement devices. In total, four measurement strategies were developed based on unique conditions. In general, it is recommended that improvement projects or phased modernization employ the same device, or a limited selection of devices, throughout the district to maintain consistency in reporting, accuracy, and operations. This also simplifies training of new employees, maintenance protocols, and troubleshooting, as well as minimizes the required spare parts. The four measurement strategies are described in Table 10.

Measurement of drain channels often presents unique challenges not often experienced in distribution canals. These include, but are not limited to: inconsistent cross sections with heavy vegetative growth, widely fluctuating flows including storm water runoff, are not typically maintained, higher than normal trash loads, below grade, low hydraulic gradients, and may be subject to additional environmental regulations.

Drain water recovery improvement recommendations focus on providing a reliable and flexible supply that can be monitored by the operators and manipulated when needed. The amount of drain water recovery is limited to available drain flows, but improvements seek to maximize its use. Effective recovery sites require: 1) infrastructure to check-up drain flows for extraction, 2) extraction device with flexible control, 3) monitoring and measurement of extraction, and 4) infrastructure or equipment in canal to provide feedback for control logic and pass recovered water to deliveries.

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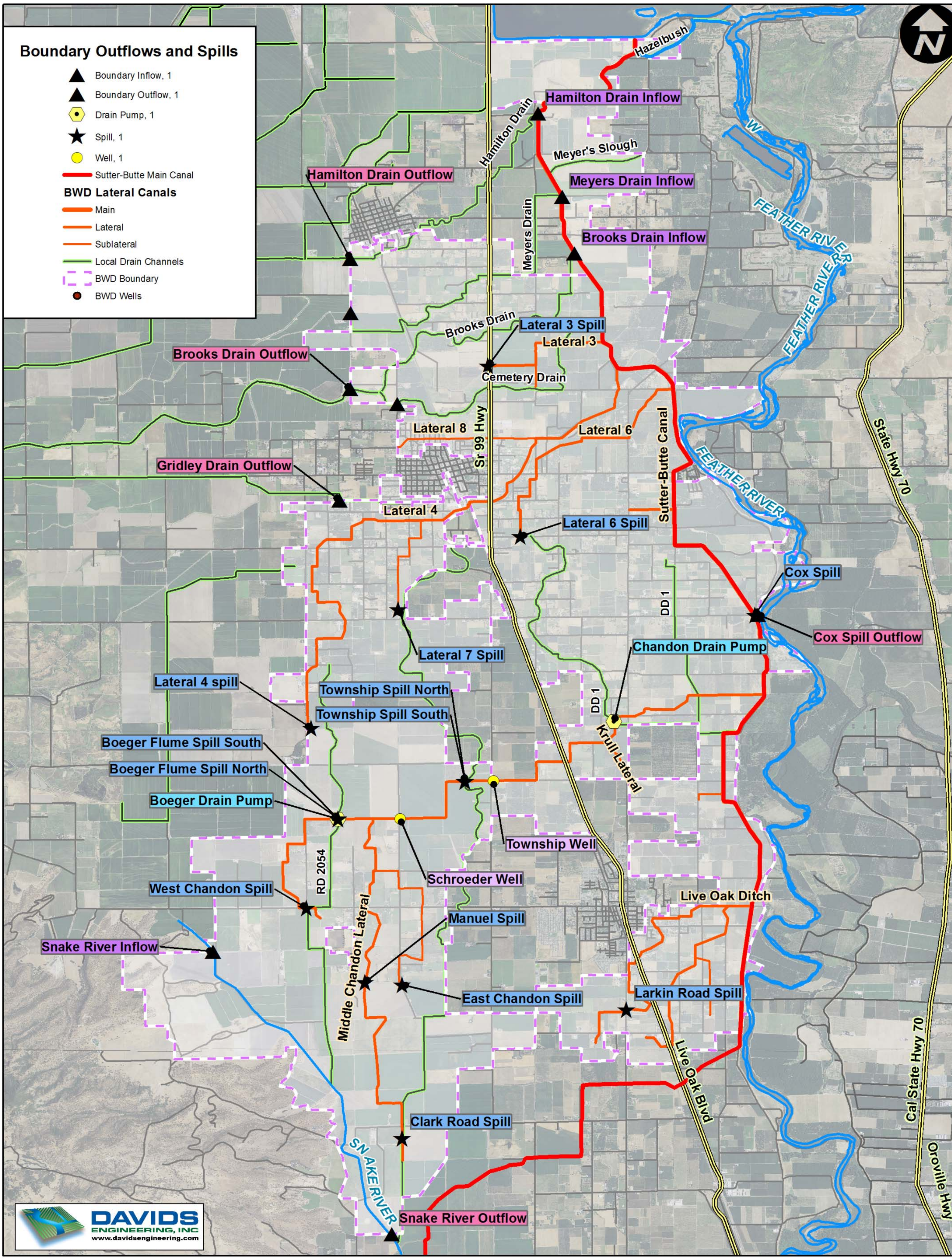

Figure 2. BWD Boundary Outflow, Primary Spills and Drain Water Recovery Sites.

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Table 10. Descriptions of Measurement Devices and Associated Advantages and Limitations.

Measurement Device	Measurement Method	Advantages	Limitations
Acoustic Doppler Meter	Doppler technology measures water velocity. Velocity X Area = Flow rate	High accuracy depending on siting. Generally little calibration and are SCADA-Ready. No moving parts.	Requires power source. Requires a stable cross section and uniform flow velocities. Weeds or other obstructions impact accuracy.
Open Channel Propeller Meter	Flow through pipe rotates propeller. Rotational velocity is related to water velocity. Velocity X Area = Flow rate	Simple and relatively inexpensive device. Can provide good accuracy depending on siting. Effective in submerged situations. District staff is familiar with technology.	Air pockets, turbulence, weeds or other trash may cause inaccuracies. Moving parts require annual maintenance. Requires full pipe.
Sharp Crested Weir	For a given weir length, flow is determined by depth of flow over weir crest.	Simple and inexpensive device. Easily adaptable to majority of existing spill structures. Good accuracy depending on siting. Minimal maintenance required.	Accuracy limited to measurement of head on weir. Requires free fall of flow over weir and uniform velocities.
RemoteTracker[7]	Portable device measures water velocity in pipeline. Velocity X Area = Flow rate	Portable. Highly accurate and simple operation. Incorporates remote communications and water delivery records.	Subject to inaccuracies caused by air pockets or turbulence. Requires full pipe. Unit cost is high. Does not provide continuous measurement.

Several of the boundary flow, spills, and drain water recovery sites are incorporated to some degree in the Modernization package as measurement of outflows is a critical component, as is reregulation and augmentation of supplies using drain water. There are several spill sites recommended for improvement in this package that are not included in the modernization package. This is because the modernization package helps define new spill routing opportunities and consolidates multiple spill sites or eliminates the need for intermediate operational spills, other than in emergency situations.

In most cases, selected spill sites are existing sites that require only minimal improvement or slight reconfiguration; however, some require complete reconstruction or new measurement method. Boundary outflow and internal outflow sites are generally new sites, but their locations are defined at the crossing of the District boundary by the conveyance channel. These sites may require the modification of the site for flow measurement accuracy or installation of the measurement device. Drain water recovery sites are all historical drain recovery sites that need refurbishment or redesign, or addition of flow measurement.

Inventory of Existing Sites

Existing sites were identified through consultation with District operations staff and digitally inventoried in tabular form and in an interactive mapping format. For each site type, several sites were selected for

[7] The RemoteTracker is a portable measurement device developed specifically as a water district delivery measurement solution in response to State of California Senate Bill x7-7. The device is currently being utilized by some Feather River water users.

field inspection to obtain dimensions, coordinates, photos and operational features typical of the site type to aid in strategy development and costing. For each site proposed for improvement, Table 11 provides the site name, the site type, latitude, longitude, and a description of the existing conditions. As previously discussed, the improvement process described here focuses on primary outflow and spill points and drain water recovery sites and may not include all minor features.

Table 11. Inventory of Existing Sites.

Site Name	Latitude	Longitude	Site Type	Description of Existing Conditions
Sutter Butte Main Canal Inflow	39.435	-121.678	Boundary Inflow	Existing SonTek acoustic Doppler flow meter installed downstream from Looney Weirs. Accuracy not verified.
Hamilton Drain	39.407	-121.716	Boundary Outflow	No measurement. Bridge abutments for W Biggs Gridley Road crossing create 16 ft wide section. Flow is channelized to approximately half of crossing width. Inflow points immediately upstream of crossing
Meyers Drain	39.420	-121.674	Boundary Inflow	Concrete headwall off of Sutter-Butte Main Canal with undershot outlet gates.
Meyers Drain	39.396	-121.716	Boundary Outflow	No measurement. Bridge abutments for W Biggs Gridley Road crossing create 8 ft wide section. Flow fills fill width with a HWL of ~2-feet. Meyers Drain and tailwater drain meet just upstream from crossing
Brooks Drain	39.408	-121.671	Boundary Inflow	Concrete headwall off of Sutter-Butte Main Canal with undershot outlet gates.
Brooks Drain	39.381	-121.716	Boundary Outflow	No measurement. Crossing at West Biggs Gridley Road is wide and shallow. Bridge abutments at Rudd Lane create 9.5-feet wide rectangular cross section. Cemetery confluence just d/s of Rudd Lane
Cemetery Drain	39.378	-121.707	Boundary Outflow	No measurement. Very deep channel between West Biggs Gridley Road and Brooks Drain. Flow is channelized under County Road crossing. Private bridge 300 feet u/s from Brooks confluence creates 10ft wide rectangular section. A 5ft diameter CMP 200ft u/s from confluence used as private crossing. Typical flow depth appears shallow in all cases.
Gridley Drain	39.358	-121.719	Boundary Outflow	No measurement. 6ft diameter RCP under Randolph Avenue approximately 0.5 miles upstream from BWD boundary. Culvert appears to have sedimentation issues
DD 1	39.311	-121.145	Boundary Outflow	No measurement. Siphon under Sutter-Butte Canal to drain channel that eventually empties to the Feather River. Large diesel powered pump provides drainage during times of high downstream flood waters
Snake River Inflow at Pennington Road	39.275	-121.753	Boundary Inflow	No measurement. 12ft wide single bay concrete weir structure upstream from County Road Crossing. Weir structure doesn't appear to be in use. Channel is approximately 8 feet deep.

Site Name	Latitude	Longitude	Site Type	Description of Existing Conditions
Snake River Outflow at SEWD Farrington Lateral	39.2068	-121.7061	Boundary Inflow	No existing measurement. Earthen channel with steep, heavily vegetated banks. A measurement site downstream from confluence with RD2056 drain will measure total inflow.
Lateral 4 Spill	39.312	-121.724	Internal Spill	No measurement. CMP weir box with 4' wide weir. HWM suggest approximately 1ft of drop across the weir boards. 20ft of 36" CMP provides drainage. Turnout immediately upstream.
West Chandon Spill	39.276	-121.725	Internal Spill	No measurement. Two bay concrete weir structure. 4ft wide x 3.5ft deep openings. One for spill one for continuation of lateral. 24" steel pipes convey water from structure to spill or lateral. Turnouts immediately upstream. Very little freeboard
Clark Road Spill	39.229	-121.706	Internal Spill	No measurement. 4ft wide weir structure with concrete headwall side spills from canal to adjacent drain channel. 18" CMP pipeline provides conveyance and free falls into drain. Pipe appears to be flow restriction
Chandon Spill	39.236	-121.706	Internal Spill	No measurement. 15" diameter sluice gate and concrete headwall. Downstream piping through embankment to adjacent drain ditch
Manuel Spill	39.260	-121.713	Internal Spill	No measurement. 3' CMP weir box upstream from crossing with 12' CMP piping to drain
Cox Spill	39.335	-121.634	Internal Spill	Existing automated overshot gate set to enable return flow of operational spills to the Feather River.
Township Spill North	39.301	-121.693	Internal Spill	No measurement. Elevated flume with side spill weir with adjustable crest height. 4' wide rectangular canal gates set so water spills over the top. Spills to RD 2056 and Morrison Slough. Four weir bays in Chandon Lateral maintain water level
Township Spill South	39.301	-121.693	Internal Spill	No measurement. Elevated flume with side spill weir with adjustable crest height. 4' wide rectangular canal gates set so water spills over the top. Spills to RD 2056 and Morrison Slough. Four weir bays in Chandon Lateral maintain water level
Boeger Flume Spill North	39.294	-121.719	Internal Spill	No measurement. 3ft wide wooden flashboard bay that spills from elevated flume to drain channel. Water level held by check structure 400-feet downstream. Manually controlled drain pump can pump from drain to lateral.
Boeger Flume Spill South	39.294	-121.719	Internal Spill	No measurement. 3ft wide wooden flashboard bay that spills from elevated flume to drain channel. Water level held by check structure 400-feet downstream. Manually controlled drain pump can pump from drain to lateral.
Lateral 3 Spill	39.38515	-121.68828	Internal Spill	No measurement. Two ~30" diameter siphons under Highway 99 exit in structure with delivery to north, delivery to south and 4ft flashboard bay to west

Site Name	Latitude	Longitude	Site Type	Description of Existing Conditions
Lateral 6 Spill	39.35066	-121.68178	Internal Spill	No measurement. 4' wide weir box upstream from Sheldon Road Crossing is regulated using boards. Spills travel through 12" RCP to East to DD1 drain
Lateral 7 Spill	39.3358	-121.70643	Internal Spill	No measurement. 3' wide concrete weir box with 12" steel pipe outlet. Trash screen at front. Not much drop, pipe may be restriction. Two deliveries immediately upstream. ~100ft of channel being converted to pipeline 700ft upstream from spill
Lateral 8 Outflow	39.369	-121.706	Boundary Outflow	No measurement. Open canal drops into 36" RCP pipe for 22' and then into open box with open flow propeller meter. Trash screen at heading of pipe. Continues in pipeline under W Biggs Gridley Road to BWGWD system
Schroader Well	39.294	-121.706	Internal Inflow	Magnetic meter currently installed on discharge piping. 300hp, 4,000 GPM, approximately 615ft well
Township Well	39.301	-121.687	Internal Inflow	No measurement. 250hp, 3,500 GPM, approximately 600ft well
Larkin Road Spill	39.25502	-121.6603	Internal Spill	No measurement. CMP weir box with 4' wide weir and concrete headwall. 50ft of 12" CMP provides drainage. Significant debris problem at this site
Hartman Spill	39.34484	-121.70643	Internal Spill	No measurement. 3ft wide weir box with concrete headwall and 24" diameter outlet pipe that empties to drain. Immediately upstream from 36" culvert in Lateral 7. approximately 0.5' of drop across weir
East Chandon Spill	39.26	-121.70564	Internal Spill	No measurement. 3' wide weir box and concrete headwall with 18" diameter outlet pipe that empties to drain. Turnout immediately upstream
Morris Spill	39.38089	-121.67869	Internal Spill	No measurement. 18' diameter culvert pipe at end of Morris Stub Lateral that drains to Cemetery. All upstream turnouts abandoned. No control on culvert. 24" sluice gate at split with Lateral 3 0.3 miles upstream

Boundary Outflow and Spill Measurement and Drain Water Recovery Physical and Operational Improvements

The two improvement packages include sites selected based on strategies described in the preceding paragraphs. For each site, improvement is split into two levels, Level 1 and Level 2. Level 1 improvements often are infrastructure and measurement enhancements that are manually operated or read, but designed as SCADA-Ready[8] sites. These improvements include, but not limited to: VFD-controlled pumps, automated gates, measuring weirs, acoustic Doppler meters, propeller meters, and RemoteTracker devices. Level 2 improvements build on the Level 1 improvements by adding electronic sensors, installing on-site digital display of flow rate or other parameters, or add remote monitoring or

[8] "SCADA-Ready" describes a package of hardware and/or software that communicates and operates locally but has been specifically designed and installed to readily accept a data transmission and receiving device (e.g. radio, cellular modem, etc.) and to provide remote communication with an established base station and SCADA human machine interface (HMI).

control through a Supervisory Control and Data Acquisition System (SCADA). Level 1 improvements are stand-alone, while Level 2 improvements generally require Level 1 to be completed prior or simultaneously. This phased implementation provides the District the flexibility to complete Level 1 (which has significant benefits on its own) while assessing the benefits of SCADA, prioritizing sites, establishing the SCADA base station and gradually implement the more complex or more expensive sites.

Although Level 2 is not universally required to be completed to obtain significant benefits, several sites will greatly benefit from it. For example, remotely located end spill sites or boundary outflow sites are not frequently visited by operators, and if they are visited and spill is noticed, it may not be worth the travel time to the heading to make a change. Remote monitoring would eliminate travel time, but does require the development of a SCADA office base station.

Additionally, in some cases, there is potentially some savings in capital costs by completing level 1 and level 2 at the same time.

Table 12 provides a description of the improvement proposed for each Boundary Flow and Primary Spill and Drain Recovery Sites. All costs are subject to revision following refinement of site improvements following more detailed review and design.

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Table 12. Summary of Boundary Outflow and Primary Spill Measurement Improvement and Drain Water Recovery Sites.

<table>
<tr><th>Site Name</th><th>Site Type</th><th>Level 1 Modernization and Enhancement</th><th>Capital Cost ($)</th><th>Annual Cost ($/yr)</th><th>Level 2 Modernization and Enhancement</th><th>Capital Cost ($)</th><th>Annual Cost ($/yr)</th></tr>
<tr><td>Sutter Butte Main Canal Inflow</td><td>Boundary Inflow</td><td>Construct concrete lined control section at location of existing meter. Perform velocity index calibration of existing meter and install walkway over sensor for verification purposes. Replace meter as necessary.</td><td>$55,400</td><td>$5,300</td><td>Upgrade and reinstall existing solar power site, flow display and communication hardware and integrate with SCADA system to allow remote monitoring of flow rate.</td><td>$5,900</td><td>$600</td></tr>
<tr><td>Hamilton Drain</td><td>Boundary Outflow</td><td>Construct control section upstream of W Biggs Gridley Road and install ADVM.</td><td>$26,400</td><td>$2,900</td><td rowspan="9">Add communication hardware to measurement site and integrate with SCADA system to provide real-time monitoring of flow rate and water level.</td><td>$5,900</td><td>$600</td></tr>
<tr><td>Meyers Drain</td><td>Boundary Inflow</td><td>Install weir box on downstream end of existing pipe and install open channel propeller meter. Install trash rack at inlet. Replace heading gate as necessary to provide adjustable and reliable control. Site will be SCADA-Ready.</td><td>$26,400</td><td>$2,400</td><td>$11,800</td><td>$1,200</td></tr>
<tr><td>Meyers Drain</td><td>Boundary Outflow</td><td>Install ADVM in existing control section created by bridge abutments</td><td>$26,400</td><td>$2,400</td><td>$11,800</td><td>$1,200</td></tr>
<tr><td>Brooks Drain</td><td>Boundary Inflow</td><td>Install weir box on downstream end of existing pipe and install open channel propeller meter. Install trash rack at inlet. Replace heading gate as necessary to provide adjustable and reliable control. Site will be SCADA-Ready.</td><td>$26,400</td><td>$2,400</td><td>$11,800</td><td>$1,200</td></tr>
<tr><td>Brooks Drain</td><td>Boundary Outflow</td><td>Install ADVM in existing control section created by Rudd Ave bridge abutments</td><td>$26,400</td><td>$2,400</td><td>$11,800</td><td>$1,200</td></tr>
<tr><td>Cemetery Drain</td><td>Boundary Outflow</td><td>Construct sharp crested weir upstream from private bridge and install water level sensor</td><td>$9,600</td><td>$700</td><td>$15,400</td><td>$1,500</td></tr>
<tr><td>Gridley Drain</td><td>Boundary Outflow</td><td>Install ADVM in pipeline. Determine if sediment is problem during irrigation season or not</td><td>$26,400</td><td>$2,900</td><td>$5,900</td><td>$600</td></tr>
<tr><td>DD 1</td><td>Boundary Outflow</td><td>Install downward looking ultrasonic sensor at crossing downstream from Sutter-Butte Canal siphon. Construct control section if needed</td><td>$26,400</td><td>$2,900</td><td>$5,900</td><td>$600</td></tr>
<tr><td>Snake River Inflow at Pennington Road</td><td>Boundary Inflow</td><td>Remove existing weir and construct BCW with level sensor</td><td>$9,600</td><td>$700</td><td>$15,400</td><td>$1,500</td></tr>
<tr><td>Snake River Outflow at SEWD Farrington Lateral</td><td>Boundary Inflow</td><td>Install ADVM in cross section formed by Farrington flume abutments. Perform velocity index calibration of measurement site and install solar power system, digital flow display and related components. Site will be SCADA-Ready.</td><td>$26,400</td><td>$2,900</td><td>Add communication hardware to measurement site and integrate with SCADA system to provide real-time monitoring of flow rate.</td><td>$5,900</td><td>$600</td></tr>
<tr><td>Lateral 4 Spill</td><td>Internal Spill</td><td>Replace weir box with new. Install sharp crested weir plate and mount custom staff gage calibrated to report spill flow rate based on the depth of water above the weir crest.</td><td>$8,700</td><td>$700</td><td>Install pressure transducer in new stilling well upstream of spill box to measure head on weir. Perform calibration of weir. Install communication hardware and integrate with SCADA system to allow remote monitoring.</td><td>$15,400</td><td>$1,500</td></tr>
<tr><td>West Chandon Spill</td><td>Internal Spill</td><td>Replace weir box with new. Install sharp crested weir plate and mount custom staff gage calibrated to report spill flow rate based on the depth of water above the weir crest.</td><td>$8,700</td><td>$700</td><td>Install pressure transducer in new stilling well upstream of spill box to measure head on weir. Perform calibration of weir. Install communication hardware and integrate with SCADA system to allow remote monitoring.</td><td>$15,400</td><td>$1,500</td></tr>
<tr><td>Clark Road Spill</td><td>Internal Spill</td><td>Remove existing concrete weir box and CMP. Install longer overpour weir with fixed crest, install drain gate and larger discharge piping to ensure free flow over weir. Install pressure transducer in new stilling well upstream of spill box to measure head on weir. Perform calibration of weir. Install communication hardware and integrate with SCADA system to allow remote monitoring.</td><td>$8,700</td><td>$700</td><td>Add communication hardware to measurement site and integrate with SCADA system to provide real-time monitoring of flow rate and water level.</td><td>$15,400</td><td>$1,500</td></tr>
</table>

<table>
<tr><th>Site Name</th><th>Site Type</th><th>Level 1 Modernization and Enhancement</th><th>Capital Cost ($)</th><th>Annual Cost ($/yr)</th><th>Level 2 Modernization and Enhancement</th><th>Capital Cost ($)</th><th>Annual Cost ($/yr)</th></tr>
<tr><td>Chandon Spill</td><td>Internal Spill</td><td>Install trash screen upstream and install weir box at downstream end of discharge pipe and install propeller meter</td><td>$26,400</td><td>$2,400</td><td></td><td>$11,800</td><td>$1,200</td></tr>
<tr><td>Manuel Spill</td><td>Internal Spill</td><td>Replace weir box with new. Install sharp crested weir plate and mount custom staff gage calibrated to report spill flow rate based on the depth of water above the weir crest.</td><td>$8,700</td><td>$700</td><td>Install pressure transducer in new stilling well upstream of spill box to measure head on weir. Perform calibration of weir. Install communication hardware and integrate with SCADA system to allow remote monitoring.</td><td>$15,400</td><td>$1,500</td></tr>
<tr><td>Cox Spill</td><td>Internal Spill</td><td>Add communication hardware to measurement site and integrate with SCADA system to provide real-time monitoring of flow rate and water level.</td><td>$11,800</td><td>$1,200</td><td>None</td><td>$0</td><td>$0</td></tr>
<tr><td>Township Spill North</td><td>Internal Spill</td><td>Replace adjustable crest gate with flap gate for emergency spill only</td><td>$8,500</td><td>$0</td><td rowspan="13">Add communication hardware to measurement site and integrate with SCADA system to provide real-time monitoring of flow rate and water level.</td><td>$0</td><td>$0</td></tr>
<tr><td>Township Spill South</td><td>Internal Spill</td><td>Remove existing gate and add boards to slots. Cut-down existing wall to create 40' long weir. Install level sensor</td><td>$6,500</td><td>$356</td><td>$0</td><td>$0</td></tr>
<tr><td>Boeger Flume Spill North</td><td>Internal Spill</td><td>Install fixed crest weir and level sensor</td><td>$8,700</td><td>$700</td><td>$15,400</td><td>$1,500</td></tr>
<tr><td>Boeger Flume Spill South</td><td>Internal Spill</td><td>Install propeller meter on drain pump inflow. Install fixed crest weir and level sensor</td><td>$19,100</td><td>$1,700</td><td>$11,800</td><td>$1,200</td></tr>
<tr><td>Lateral 3 Spill</td><td>Internal Spill</td><td>Install trash rack upstream of siphon. Install fixed crest weir and level sensor.</td><td>$8,700</td><td>$700</td><td>$15,400</td><td>$1,500</td></tr>
<tr><td>Lateral 6 Spill</td><td>Internal Spill</td><td>Replace trash screen upstream and install weir box at downstream end of discharge pipe and install propeller meter</td><td>$26,400</td><td>$2,400</td><td>$11,800</td><td>$1,200</td></tr>
<tr><td>Lateral 7 Spill</td><td>Internal Spill</td><td>Replace existing pipeline with larger diameter (15") HDPE pipe. Install fixed crest weir and level sensor</td><td>$8,700</td><td>$700</td><td>$15,400</td><td>$1,500</td></tr>
<tr><td>Lateral 8 Outflow</td><td>Boundary Outflow</td><td>Perform validation of propeller meter reading</td><td>$4,000</td><td>$219</td><td>$11,800</td><td>$1,200</td></tr>
<tr><td>Schroeder Well</td><td>Internal Inflow</td><td>None</td><td>$0</td><td>$0</td><td>$0</td><td>$0</td></tr>
<tr><td>Township Well</td><td>Internal Inflow</td><td>Add magnetic meter</td><td>$9,000</td><td>$493</td><td>$11,800</td><td>$1,200</td></tr>
<tr><td>Larkin Road Spill</td><td>Internal Spill</td><td>Replace structure and pipe with new inlet (with trash screen) and outlet weir boxes and HDPE pipe. Install propeller meter in downstream end</td><td>$26,400</td><td>$2,400</td><td>$11,800</td><td>$1,200</td></tr>
<tr><td>East Chandon Spill</td><td>Internal Spill</td><td>Install weir box on discharge end and install propeller meter. Install trash screen on upstream side</td><td>$26,400</td><td>$2,400</td><td>$11,800</td><td>$1,200</td></tr>
<tr><td>Morris Spill</td><td>Internal Spill</td><td>Cut-down top of headwall at Stubbs heading, install board guides and add fixed crest. Install level sensor. Retain sluice gate, remove discharge pipe.</td><td>$8,700</td><td>$700</td><td>$15,400</td><td>$1,500</td></tr>
<tr><td>Chandon Drain Pump</td><td>Drain Water Recovery (Pump)</td><td>Install flow meter on pump discharge piping to enable improved manual control.</td><td>$6,500</td><td>$356</td><td rowspan="2">Add communication hardware to measurement site and integrate with SCADA system to provide real-time monitoring of flow rate.</td><td>$11,800</td><td>$1,200</td></tr>
<tr><td>Boeger Drain Pump</td><td>Drain Water Recovery (Pump)</td><td>Rebuild pump as necessary. Install flow meter on pump discharge piping to improve manual control.</td><td>$6,500</td><td>$356</td><td>$11,800</td><td>$1,200</td></tr>
</table>

Project Costs

Costs for the Boundary Outflow and Primary Spill Measurement Project

Reconnaissance level cost estimates were prepared for both improvement packages described in the preceding sections as a basis for prioritization and funding of site improvements. For the Boundary Flow and Primary Spill Measurement package, the total combined cost (Level 1 and Level 2) of improvement is approximately $821,000, with estimated annualized costs of $78,000. Total costs are further summarized in Table 14.

Table 14. Summary of Costs.

	Level 1		Level 2	
Boundary Flow and Primary Spill Measurement	Capital Costs ($)	Annual Costs ($)	Capital Costs ($)	Annual Costs ($)
Boundary Flows Subtotal	$294,800	$29,393	$107,500	$10,800
Spills Subtotal	$225,100	$18,675	$194,000	$19,200
Total Cost =	$519,900	$48,068	$301,500	$30,000

Costs for the Drain Water Recovery Project

The total cost of improving or developing the 2 drain recovery sites is $37,000 with an estimated annualized cost of $3,000 Total costs are further summarized in Table 15.

Table 15. Summary of Costs.

	Level 1		Level 2	
Drain Water Recovery	Capital Costs ($)	Annual Costs ($)	Capital Costs ($)	Annual Costs ($)
Total Cost (2 Sites) =	$ 13,000	$ 712	$ 23,600	$ 2,400

The aforementioned costs do not include a SCADA base station (which would be required for Phase II) or any mobile operator terminals that would form the backbone of the District SCADA system, or any costs of spare equipment to be kept on hand to repair or replace individual site components due to theft, vandalism, or other failure. These costs are summarized in Table 16. This cost represents a robust SCADA network that would be capable of monitoring the identified measurement and drain recovery sites as well as existing or future sites, such as detailed in the Modernization program. The cost of the office base station may be drastically reduced, or eliminated, if the District is able to 'piggy-back' on to and expand the existing SCADA network owned and operated by the Joint Water Districts and Joint Board.

Table 16. Summary of Costs for SCADA Office Base Station and Spare Parts.

Item	Capital Cost ($)	Annual Cost ($)
SCADA Office Base Station	$138,063	$17,039
Spare Parts	$23,692	$2,913

Potential Benefits

Boundary Flow and Primary Spill Measurement and Drainwater Recovery

Flow paths targeted under the boundary flow and primary spill measurement and drainwater recovery projects are:

- Operational spillage
- Tailwater
- Drainage Outflows
- Diversions

Measurement of boundary flows and spills provides operators the tools to reduce operational losses. Reduction in losses may result in decreased required diversions. Reuse of operational spillage and tailwater results in decreased required diversions. Because BWD water users rely on drainwater in many cases, improvements would increase the functionality of these sites, but not necessarily result in additional conserved water.

Available water not diverted remains in storage and could potentially be available to meet local, regional, or statewide water management objectives. Through implementation of these projects, it is estimated that approximately 5 to 15 percent[9] of existing boundary outflows during the irrigation season could be conserved annually, or between approximately 3,500 and 10,500 af per year depending on the level of implementation.

Net Benefit Analysis

The district is currently implementing associated EWMPs at locally cost-effective levels. BWD has not used its full allocation in recent years, and thus would not achieve cost savings through additional conservation. The estimated implementation cost per unit of water conserved ranges from approximately $10 to $29 per acre-foot. As a result, further implementation of the boundary outflow and primary spill measurement and drainwater recovery project is not locally cost effective at this time. In the future, it is anticipated that the costs and estimated benefits of this improvement project will be evaluated as additional information becomes available.

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[9] Based in part on percent reductions in spillage for various improvement measured listed in the technical memorandum “Spillage Reduction- Monitoring and Verification” published by the Agricultural Water Management Council, and partly on experience with local conditions and judgment.

Project 3: Removal of Sutter-Butte Canal Bottlenecks

Project Description

The Sutter-Butte Canal upstream of the Sunset Pumps has two structures that limit capacity: the Looney Weir and the Rio Benito Road Bridge. The objectives of this project are to reconstruct these two sites with increased capacity structures to prevent them being a limitation to meeting downstream demand. Additionally, the Rio Benito Road Bridge has been identified as potentially being structurally inadequate and is scheduled to be replaced by the County at a future, unidentified date.

The Looney Weir is located in the Sutter-Butte Canal approximately 2 miles downstream from Thermalito Afterbay. The current capacity of the two AMIL gates is estimated at 900 cfs, but the installation of a parallel bypass gate pipe increases the structures capacity to approximately 960 cfs. Required capacity at this point to meet demand is approximately 1,000 cfs. The Rio Benito Bridge is located approximately 0.5 miles downstream from the Looney Weir. The bridge consists of concrete abutments and several concrete pile piers at the canal midsection, parallel to the flow. The location of the abutments decreases the width of the channel and limits capacity.

For each site to be improved, conceptual designs developed as part of the Sutter Butte Regional Conveyance Study[10] were revaluated to ensure consistency with the objectives and costs were updated to reflect normal inflation of construction costs and to account for prevailing wage rates likely to be required if grant funding was secured for implementation. Approximately five additional bottlenecks were identified along the Sutter-Butte Canal, but these are within the boundaries of SEWD and are discussed in a separate attachment.

Inventory of Existing Sites

Existing sites were identified through consultation with district operations staff. Each site was visually inspected to obtain coordinates, photos and operational features to aid in strategy development and evaluation of improvement costs.

Physical and Operational Improvements

Table 17 provides a description of the existing site condition and the improvement proposed for each of the two bottleneck removal sites. All costs are subject to revision following refinement of site improvements following more detailed review and design.

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[10] GEI Consultants, 2006. Regional Conveyance System Improvement Project – Final Report, May 2006. Completed for Sutter Extension Water District by Bookman-Edmonston, a division of GEI Consultants, Inc.

Table 17. Summary of Improvements for Bottleneck Removal.

Site Name	Latitude	Longitude	Description of Existing Conditions	Description of Operational Objective with Improvements	Description of Proposed Improvement	Capital Cost ($)	Annual Cost ($/yr)
Looney Gates	39.436	-121.678	Two ~16ft wide AMIL gates installed in concrete structure. Approximate capacity is 900cfs.	Increase capacity of structure to 1000cfs+ to meet the downstream demands.	See Joint Board Improvement Description. Remove existing AMIL gates and construct new structure with minimum capacity of 1,000 cfs.	$493,947	$27,057
Rio Benito Bridge	39.428	-121.678	Concrete abutments with wing walls. Center pier consists of four round piles parallel to flow. Abutments create narrow spot in canal.	Remove flow restriction and increase capacity of section to the same as adjacent Main Canal sections	Demolish existing bridge, bridge abutments, and center pier and replace the structure with a wider, sturdier structure. Reconstruct canal in immediate vicinity to remove flow restriction.	$375,273	$20,556

Project Costs

Reconnaissance level cost estimates were prepared for both improvement projects described in the preceding sections as a basis for prioritization and funding of site improvements. The total combined cost of removing and replacing the bottlenecks is approximately $869,000, with estimated annualized costs of $48,000. Individual site costs are summarized in Table 18.

Table 18. Summary of Costs.

Bottleneck Removal	Capital Costs ($)	Annual Costs ($)
Looney Weir	$493,947	$27,057
Rio Benito Road Bridge	$375,273	$20,556
Total Cost =	$869,221	$47,613

Potential Benefits

The removal of the two identified bottlenecks have no quantifiable water conservation benefits; however, other benefits for BWD may include:

- Increased capacity to meet downstream irrigation demand (limited to downstream canal capacity constraints) may enable increased rotational frequency or larger available irrigation heads. This may increase irrigation efficiency.
- Reduced reliance on Sunset Pumps by SEWD. May incentivize joint projects between BWD and SEWD.
- Increased ability to meet refuge and other water user demands (limited to downstream canal capacity constraints).
- Potential for avoided labor required to make frequent gate adjustments.
- Increased safety and structural adequacy of structures.

Additional flow capacity at the heading could reduce the reliance of SEWD on the Sunset Pumps and decreasing annual pumping costs. The benefits of this can be estimated by assuming that pumping could be offset by approximately 100 cfs during periods when demand exceeds current capacity (typically only in May of each year during the peak rice flood-up period). It is estimated that the Sunset Pumps require approximately 43 kilowatt-hours of electricity to pump one af of water[11], so a continuous offset of 100 cfs for the month of May corresponds to an approximate savings of $40,000 at an electrical rate of $0.15 per kWh. The monetary benefit to SEWD may incentivize cost-sharing on mutually beneficial projects elsewhere on the Main Canal.

[11] Referenced from Table 1. Sunset Pumps pump test information (Durham Pumps, Fall 2003) in the Rapid Appraisal Report prepared for Sutter Extension Water District by the Irrigation Training and Research Center, June 2007.

Net Benefit Analysis

A net benefit analysis was not performed for this project because the improvements are not categorized as an EWMP. Increased water supply for Sutter National Wildlife Refuge has been evaluated as part of the Sutter Butte Regional Conveyance Study[12].

[12] GEI Consultants, 2006. Regional Conveyance System Improvement Project – Final Report, May 2006. Completed for Sutter Extension Water District by Bookman-Edmonston, a division of GEI Consultants, Inc.

Project 4: Alternatives for Improving Delivery Service to Pressurized Irrigation Systems

Project Description

Butte Water District is a unique district when compared to the primary Feather River water users because, unlike Western Canal Water District, Richvale Irrigation District, and Biggs West Gridley Water District, only approximately 48 percent is occupied by crops in which level basin or flood irrigation is best suited (rice and pasture). The remaining 52 percent are permanent crops or other miscellaneous crops. Because of this high percentage of permanent crops, many growers in BWD are converting to pressurized micro irrigation systems (e.g. drip, micro sprinklers) to take advantage of various agronomic, labor, water conservation, and economic benefits. These irrigation methods typically require a small flow rate for a long duration and at a high frequency which is inconsistent with the irrigation scheduling and methods that were historically used for these crop types. Providing this level of flexibility is difficult and puts additional strain on the system and its operators. In some cases, this has adversely affected service and has caused an increasing number of growers to switch from surface water to groundwater which can be more flexible and typically requires less filtration then District supplied water. The use of District water typically requires two types of filtration for micro irrigation systems: a coarse filter to remove large debris, and a fine filter to remove smaller particles. The filters must be routinely flushed to remove debris, requiring additional water and requiring infrastructure to collect or convey debris.

In general, the objective of this improvement project is to identify opportunities to provide flexible deliveries at a frequency, rate and duration that will incentivize growers to utilize surface water over groundwater.

The delivery service required by pressurized irrigation is very similar to the maintenance flows that the District must provide to rice fields during the majority of the growing season. Therefore, it is anticipated that laterals that serve both rice and permanent crops are suited to meet the frequency, rate and duration requirements, but likely fall short in filtration and water quality. Canals that serve primarily permanent crops are subjected to common difficulties with providing flexible service to pumped deliveries, as listed below:

1. Long durations and small flow rates require supply canals to remain filled for a longer period when compared to a rotational system. This increases losses and requires a small maintenance flow which is difficult if canal control is limited.
2. High frequency, long duration and small flow rate deliveries inevitably lead to many simultaneous deliveries that require a large portion of the system (if not all) to be filled throughout the irrigation season.
3. Pumped deliveries require a constant supply to prevent pump damage. This is nearly impossible to supply in an open canal system without storage or supplying extra water to the lateral to ensure the pump doesn't run dry. The latter typically leads to spillage.
4. Power failures, mechanical failures or other unannounced shutoffs cause fluctuations in water levels requiring intensely vigilant operators or result in spillage.
5. Water ordering is difficult in an open system with pump deliveries because uncertainties in rotation, duration, demand rate, etc. are high. This often leads to excess water being ordered and spilled if not used.

Based on a field tour of BWD, observation of irrigation systems, field layouts, delivery gates, and conveyance infrastructure, several improvement alternatives were identified that have the potential to improve service to pressurized irrigators. These are listed below in no particular order:

1. Construct regulating storage within in the system to enable flexible service while minimizing spillage.
2. Construct intertie pipelines between adjacent laterals to increase the downstream demand area available for use of spill or excess water supplied to prevent pump damage.
3. Convert laterals with concentrated pressurized irrigation to buried, mechanically pressurized supply pipeline and delivery network.
4. Construct group turnouts in areas with high concentration of pump deliveries to minimize labor requirements.
5. Construct on-channel pumping sumps to accommodate on-farm pressurized irrigation systems and minimize filtration requirements.
6. Install manual filtration screens (coarse filtration) at the heading of each lateral.
7. Install manual filtration screens (semi coarse filtration) at each pressurized turnout.
8. Install automated filtration screens (semi fine filtration) at the heading of each lateral.
9. Install automated filtration screens (semi fine to fine filtration) at each pressurized turnout.
10. Develop construction and technical standards for growers interested in connecting to the District system. This will standardize turnouts and provide the opportunity to add flow measurement and possibly remote monitoring to each pump to provide operators with real-time information on pump status and pumping requirement.

Although alternatives 1 and 2 above are conventional methods for increasing flexibility (among other benefits), a high level review did not identify any sites in BWD with anticipated benefits significant enough to justify further analysis. The remaining alternatives can be generally packaged into three categories: Conversion to Pressurized Laterals, Improvement of Turnout Configurations, and Debris Management. The physical or operational components associated with each of these categories, or packages, are described in additional detail in subsequent sections.

Physical and Operational Improvements

Conversion to Pressurized Laterals

In general concept, conversion of an open channel delivery system to a closed, pressurized delivery network is complicated and requires extensive analysis to quantify all associated costs and benefits. For purposes of this analysis, several simplifying assumptions were made to provide a generalized, high-level estimate of probable costs to assist in prioritization of improvements and consideration for more detailed, feasibility-level designs.

Conversion to pressurized laterals is generally only considered at a conceptual level if a lateral can be identified with a high concentration of permanent crops and existing infrastructure cannot provide the required service level. For BWD, the Live Oak Lateral and the Webster Laterals serve an estimated 950 acres of primarily permanent crops on the southeastern edge of the district boundary making it a likely candidate for consideration. A conceptual design of a pressurized delivery network was developed by making the following assumptions:

1. Demand estimated at 8 GPM/acre and increasing to 10 GPM/acre in the downstream-most pipe segments to provide a similar level of service as those at the upstream end.
2. The minimum turnout pressure supplied by the network would be 30 psi to be compatible with most micro irrigation systems.
3. Electric motors and centrifugal pumps would pump from the Sutter-Butte Canal to supply the pipeline. No reservoir would be required.
4. Turnouts would be spaced at intervals of 450 ft along the laterals to provide the pressurized service to growers.
5. Ground surface elevations from head to tail, and total lengths of existing conveyances estimated using Google Earth.

Based on the listed assumptions, the design outputs for the conceptual design are summarized in Table 19.

Table 19. Summary of Design of Pressurized Laterals.

Total Pipeline Length, LF	19,000
Minimum Pipe Size, inches	10
Maximum Pipe Size, inches	30
Maximum Flow Rate, GPM	8,205
Minimum Supplied Pressure, PSI	30
Estimated TDH, FT	95.3
Estimated Total HP required	222

The pressurized lateral conceptual design included fully adjustable pressurized turnouts fitted with inline flow meters and pressure gages, all air/vacuum vents, pressure relief valves, isolation valves, fittings and other miscellaneous appurtenances required for a fully operational supply network. The pump station would include a pumping sump, pump stands, electrical power, variable frequency control, primary flow measurement, discharge manifold, and all related site features.

Improved Turnout Configuration

The improved turnout configuration package includes two alternatives for improved infrastructure, and a the description of a standardization process that could be implemented by the District to facilitate adoption of formal rules regarding the supply of on-farm pressurized irrigation systems, and enable some enforcement and control over the connection details which, in the end, will likely enable enhanced delivery service.

A conceptual design for improved turnout specifically for on-farm pressurized irrigation systems would include a rectangular concrete structure with one open side integrated into the side of a supply canal such that the pump intake is located out of the channel (minimizing canal flow restriction), but has an ample supply of water (assuming the canal stays full), and any debris can be manually or automatically cleaned from the intake screen and swept downstream. This alternative simplifies District operational effort and provides increased flexibility and cost savings potential (due to reduced filtration requirements) for the grower.

The construction of group turnouts along laterals with high concentration of on-farm pressurized systems would require the reconfiguration of certain reaches of canal into essentially level-top pools.

This provides limited storage in the vicinity of turnouts, reduces the effects of upstream or downstream fluctuations and maintains a constant water level for more efficient pumping. Additionally, one level-top pool is generally simpler to operate than several individual turnout locations.

Debris Management

Screening debris at strategic locations in the District laterals would provide several advantages to overall operations and to system efficiency. Although cleaning screens throughout the season would potentially require additional staff time, significant time, effort, and expenses could be saved by preventing canal overtopping, structures washing out, and expensive canal cleaning operations while providing improved service to customers. Specific sites have not been identified for BWD, but likely locations are the head of primary laterals and at the upstream ends of siphons or road crossing. Optimally, screens would be located and positioned so that it prevent debris from entering the channel, but allows the sweeping velocity to pass the debris downstream.

Simple bar screens with manual cleaning are likely the most cost effective and justifiable option for the majority of locations in the system; however, a mechanical chain screen that is self-cleaning may be preferable for areas with high debris load or sensitive pump intakes. A screen that physically extracts the debris is advisable at sites where there is no sweeping flow that could move debris downstream (e.g. at a dead end lateral). For turnout filtration, sloping punch plate screens provide semi-fine filtration and have a smooth surface that allows debris to more easily be swept downstream. Automatic turnout screens that mount to the pump intake piping provide fine filtration and are self-cleaning typically using a combination of a rotating screen and a water nozzle.

The installation of manual trash screens requires regular (i.e. daily) inspection by the operator and the removal of accumulated trash as necessary. This could likely be incorporated into daily operations. Screens would be designed with bars sloping downstream so the velocity of the passing water pushes floating debris to the upper portions of the screen (above the water surface) thereby minimizing flow restrictions. This also makes them easier to clean.

In addition to the three improvement categories described above, the replacement of heading structures, water level control structures, and spill structures would improve operations, enabling steadier deliveries, more rapid passage of flow fluctuations to meet demands, and monitoring to inform changes and notification of issues (though SCADA implementation). These outcomes would likely increase the level of service provide to pressurized deliveries. The System Modernization Program provides additional descriptive information, site specific improvements, and related costs.

Project Costs

Reconnaissance level cost estimates were prepared for each of the three improvement categories and the alternatives in each. The costs (Table 20) serve as a basis for prioritization and funding of site improvements. Individual projects costs are provide as unit values in some cases to enable costs to be estimated for sites with varying requirements. Annual costs for the conversion to pressurized laterals include estimations of required energy costs.

Table 20. Summary of Costs.

Improvement	Estimated Total Cost ($)	Annual Costs ($)	Unit
Conversion to Pressurized Laterals			
Conceptual Cost Estimate for Sunset and Webster Lateral =	$2,415,500	$333,212	LS
Cost per Acre =	$2,500		$/AC
Cost per linear foot of pipe =	$200		$/LF
Cost per CFS =	$132,200		$/CFS
Improved Turnout Configuration			
Development of Standardized Turnout Design and Technical Specifications =	$5,000	$274	LS
Design and Construction of On-Channel Pump Sump (includes self-cleaning screen) =	$13,600	$745	LS
Debris Management			
Sloped Vertical Bar Screen =	$45		per SF
Automatic Rotating Chain Screen =	$1,100		per SF
Sloped Punch Plate Screen =	$30		per SF
Self-Cleaning Intake Screen (12" diameter) =	$4,000		EA

Potential Benefits

The primary quantifiable benefit to the District with this improvement project is retaining surface water customers to sustain the groundwater system while maintaining reliable revenue from water sales that covers operations and maintenance costs. BWD is active in the management of the local groundwater basin and recognizes the benefits of conjunctive use of available water supplies and encourages the use of surface water to maintain net positive recharge of the aquifer.

Lateral pressurization offers additional unique benefits, including:

- Potential for improved air quality due to centralized pumping and reduction of potentially inefficient on-farm units.
- Potential for water conservation due to the incentive to convert to more efficient irrigation methods.
- Potential for increased crop yields to improved water management.
- Potential reductions in on-farm operations costs associated with irrigation, filtration, and power costs.

Net Benefit Analysis

A net benefit analysis was not performed for this project because the District is already implementing this EWMP at a locally cost-effective level. In the future, it is anticipated that the costs and estimated benefits of this improvement project will be evaluated as additional information becomes available.

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4.10.4 Drought Management Plan

Background and Overview

Note: The Drought Management Plan (DMP) contained herein was developed per Executive Order B-29-15 issued by Governor Brown on April 1, 2015 and included in the District's 2015 AWMP update. BWD is not legally required to update their AWMP but is voluntarily electing, at their own expense, to update sections of their AWMP. The DMP has not been updated in accordance with the requirements of AB 1668 in the 2020 AWMP update as the District is voluntarily updating other sections of the Plan.

On April 1, 2015 Governor Brown issued Executive Order B-29-15, mandating agricultural water suppliers to include a detailed Drought Management Plan (DMP) describing actions and measures taken to manage water demand during drought. BWD has historically experienced relatively reliable water supplies with a full surface water supply of 133,000 acre-feet available in all but four years (1977, 1991, 1992, and 2015) since construction of Lake Oroville and its subsequent 1969 settlement agreement with the State. During years in which curtailment is allowed under the agreement, BWD's water supply can be reduced by up to approximately 50 percent, as discussed in greater detail below.

The District recognizes the need for fair, consistent policies to address periods when customer demands exceed available surface water supplies. This DMP describes and expands upon BWD's shortage allocation policies, including discussion of a broad range of actions undertaken during drought to manage available water supplies and meet customer demands to the maximum extent possible.

The DMP includes components recommended by DWR in its 2015 AWMP Guidebook (DWR 2015). BWD's DMP describes the determination of available water supply, drought responses, and water shortage impacts. The description of water shortage impacts includes a discussion of 2015 supply and demand conditions available at the time of preparation of this DMP. A description of supplies and demands for 2013 and 2014, also required under Executive Order B-29-15, is included in the water balance section of this AWMP (II.4.7).

As stipulated in the 1969 agreement, BWD's water supply depends on Lake Oroville inflow. BWD's surface water supply can be reduced under the following conditions:

- DWR forecasted April to July unimpaired runoff into Lake Oroville is less than 600,000 af[13], or
- Total current year predicted and prior year actual deficiencies in unimpaired runoff (as compared to 2,500,000 af) exceed 400,000 af for one or more successive prior water years with less than 2,500,000 af of runoff.

When a reduction is allowed, the Joint Board allotment of 555,000 af can be reduced by up to 50 percent in any one year, but not by more than 100 percent in any seven consecutive years.

[13] The final, official forecast must be made by April 10 of each year.

Additionally, reductions in any given year cannot exceed the percent reduction experienced for agricultural use by State Water Project (SWP) contractors.

Historically during years of curtailment, DWR has curtailed Joint Board water supplies by the full allowed amount, 50 percent, in each instance. For BWD, which is entitled to 24 percent of the Joint District supply, the curtailment year apportionment is 66,500 af.

Additionally, under the 1969 settlement agreement, the Joint Districts receive an additional 35,000 af of surface water supply in a year with 50 percent reduction. This 35,000 af is divided equally among the Joint Districts, providing an additional 8,750 af to each. As a result, BWD's surface water supply in a year with 50 percent reduction is 75,250 af, or approximately 57 percent of the normal year supply of 133,000 af.

Despite water supply being dictated by the 1969 settlement agreement with the State, monitoring of hydrologic conditions to assess available water supply is important to BWD's water management across the full range of hydrologic conditions experienced. To inform District decisions related to available water supply and to inform growers of supply conditions, the District actively monitors water supply information reported by the Department of Water Resources (DWR) and others for Lake Oroville and the Feather River watershed as a whole. Information monitored includes storm activity, accumulated precipitation and snow, water year indices, reservoir storage and releases, and projected and actual reservoir inflow. This valuable information supports the District and its customers in planning for water management and in making cropping decisions in all years. The value of monitoring a broad range of hydrologic information is amplified in years of drought.

Drought Responses

This section describes actions and activities undertaken by BWD to address surface water shortage, including discussion of existing shortage allocation policies, coordination and collaboration, supply management and demand management.

<u>Shortage Allocation Policies</u>

During past shortage years, BWD has reduced demands through mandatory idling of a portion of the acres planted to rice and a reduction in the number of irrigations provided to orchards. Typically, orchards receive six to eight irrigations per year. Under a 50% reduction in surface water supplies, it is estimated that only three or four irrigations would be made available. Water shortage allocation policies are evaluated on a year by year basis by the board of directors and modified as appropriate.

In addition to the two groundwater wells owned by the district, it is estimated that there are more than 220 operable private irrigation wells within the BWD service area, some of which have the potential to supplement surface water supplies in cut back years. Many of these wells serve as the primary source of irrigation supply in all years.

Coordination and Collaboration

BWD coordinates and collaborates extensively with others regarding local and regional water management in all years. These activities intensify during periods of drought in order to minimize adverse drought impacts across a range of stakeholders. Examples of collaboration and coordination activities include the following:

- Regular coordination with the other Joint Districts, WCWD, and DWR with regard to Feather River water supplies and demands, including monthly or more frequent calls with DWR SWP operators.
- Reporting of information to DWR and other governmental entities as necessary.
- Close coordination with Butte and Sutter counties regarding groundwater conditions and monitoring.
- Outreach to interested parties including Farm Bureau, legislators and legislative staff, government agency staff, media representatives, and others regarding surface water and groundwater management.

Supply Management

Extraordinary Operational Measures

In recent years, BWD has made improvements to both distribution system infrastructure and operational practices to improve overall distribution system management and to increase operational efficiency. During periods of surface water shortage, BWD takes additional, extraordinary measures to further increase operational efficiency and to maximize the beneficial use of available water supplies. Highlights of BWD activities to increase operational efficiency include the following:

- Adoption of the 2014 Feather River Regional Agricultural Water Management Plan (FRRAWMP), which included the identification of approximately $18 million in modernization and boundary flow measurement improvements. These projects have the potential to substantially increase operational efficiency. It is anticipated that these improvements will be implemented over time subject to funding and project prioritization.
- Increased coordination among operators and with customers to reduce surface outflows resulting from operational spillage and tailwater. These improvements are achieved through a combination of more frequent spill monitoring and more frequent flow adjustments in the system in response to grower demands.
- Implementation of a policy to allow for more flexible use of private pumping capacity.
- Increased coordination with the JWDB manager and SWP operations to more flexibly divert water and to closely and continuously track diversion amounts.

Supply Augmentation

BWD water supplies have been generally sufficient during years with full surface water supply. Historical contributions of surface water recharge to the underlying groundwater system allow growers within BWD to utilize available groundwater in years of surface water shortage to augment available water supplies. The District owns two groundwater wells that are typically used for groundwater substitution to increase local and statewide water supplies during drought and other dry years. BWD allows growers to optimize the use of available groundwater during drought through its pumping policy. The conjunctive management of surface water and groundwater supplies is a key component of BWD's drought management strategy.

Demand Management

BWD encourages efficient on-farm water management to control demand on an ongoing basis. During curtailment years, these efforts are enhanced through extraordinary actions, which may include the following:

- Additional education and outreach, including grower meetings and individual consultations.
- Allocation of available water supplies, including limitation of winter water use in 2014 (a full supply year) and limited summer and winter water use in 2015 (a curtailment year).
- Enhanced enforcement of rules and regulations.

These actions are summarized in the remainder of this section.

Outreach and Incentives

During periods of reduced supply, BWD increases outreach efforts to encourage on-farm water conservation and to keep growers informed of hydrologic conditions and any changes to BWD policies and practices to manage limited water supplies. In years of supply reduction, District staff meet with growers prior to the start of the irrigation season to discuss surface water availability and water management objectives and opportunities.

Allocation of Available Supplies

Under reduced surface water supply conditions, BWD apportions available surface water as described previously under its shortage allocation policies.

Enhanced Enforcement of Rules and Regulations

BWD's Rules and Regulations (AWMP Attachment II.4.10.2) disallow the waste of water (Rule 17). Under this rule, BWD has the authority to refuse delivery of water until wasteful conditions are remedied. During periods of water supply shortage, BWD may increase enforcement of rules related to the waste of water. Apportionment of surface water supplies during shortage years implicitly discourages water waste.

Water Shortage Impacts

Supplier Revenues and Expenses

The District's water charges are determined using a fixed (per-acre) rate dependent on the time of year (summer vs. winter). As a result, revenues have been greatly reduced in curtailment years due to large reductions in planted acres. In addition to reduced water charges to irrigation customers, revenues decrease as a result of decreased water sales through water transfers.

In addition to reduced revenues during curtailment years, operating costs increase substantially due to several factors. Increased expenditures include the following:

- Increased staff time providing enhanced operations, irrigation customer service, and outreach to the public.
- Increased reliance on outside water management assistance (consultants and legal) for Lake Oroville operations coordination, water rights protection, and other drought-related issues.
- Increased weed control costs due to low canal flows.

Impacts on Water Supplies

To illustrate actions by BWD and its customers to manage available water supplies during drought, water supplies for 2015 are summarized and compared to prior years. The years 1999 through 2014 represent years where the full surface water supply was available for diversion by BWD. The year 2015 represents a year in which the District's normal JWDB supply of 133,000 af was curtailed by 50%, representing an overall reduction of approximately 43% of BWD's JWDB supply due to the availability of an additional 8,750 af through the 1969 settlement agreement with the State, as described previously.

Average April through October diversions for BWD from 1999 to 2014 and for 2015 are shown in Figure 1. Total average diversions between April and October were 97,000 af between 1999 and 2014 and 76,000 af in 2015.

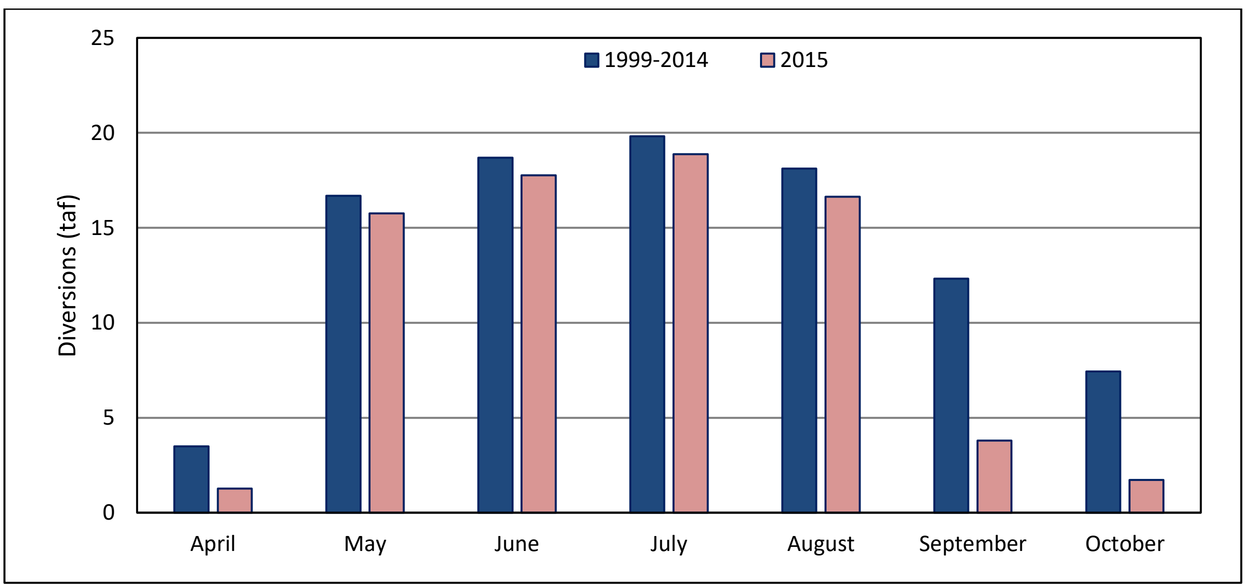

Figure 1. BWD April to October Diversions, 1999-2014 Average and 2015.

Average monthly estimates of groundwater pumping for BWD from 1999 to 2014 and for 2015 are shown in Figure 2. The increase in groundwater pumping in 2015 in response to curtailment was approximated by estimating the additional acreage irrigated using groundwater in 2015 in response to curtailment (3,600 acres) and assuming an average duty of 4.0 af/ac. Thus, the total additional pumping resulting from curtailment is estimated to be approximately 14,400 af. Considering baseline private pumping within BWD's service area, total April to October pumping during 2015 was estimated to be 34,000 af. Monthly pumping volumes shown in Figure 2 were estimated based on the portion of estimated irrigation demand occurring each month.

Total diversions and groundwater pumping, which represent the primary sources of irrigation supply in BWD, are shown in Figure 3. Total average diversions and groundwater pumping between April and October were 116,000 af between 1999 and 2014 and 109,000 af in 2015.

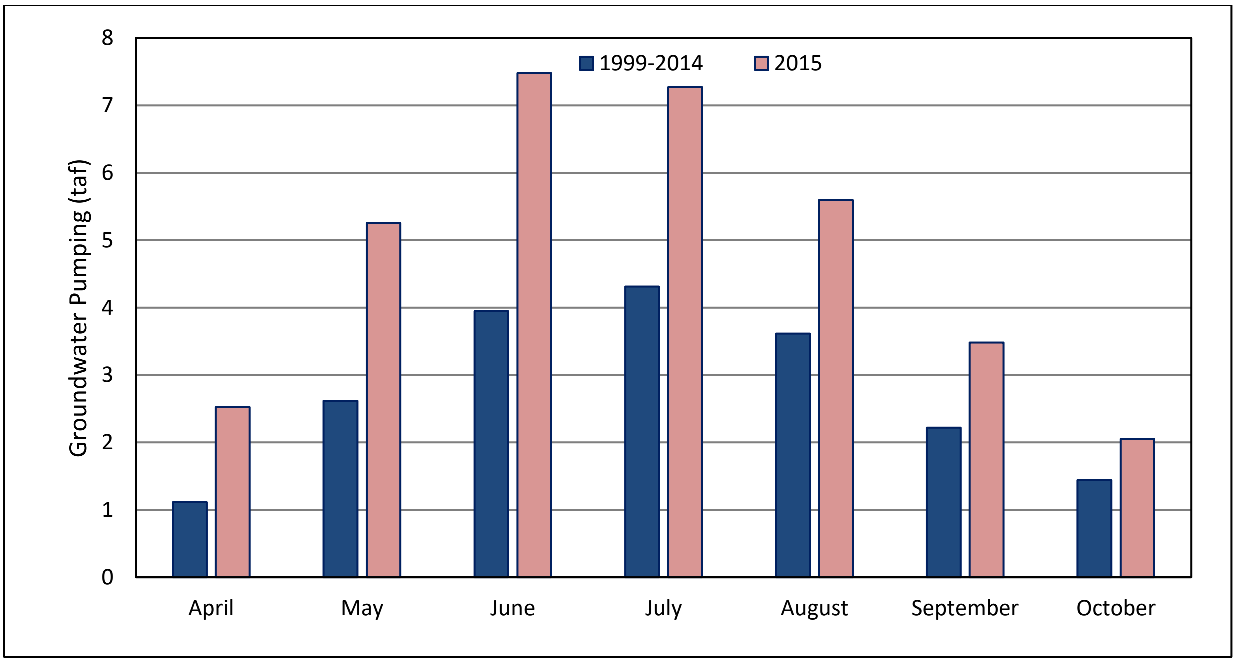

Figure 2. BWD April to October Private Groundwater Pumping, 1999-2014 Average and 2015.

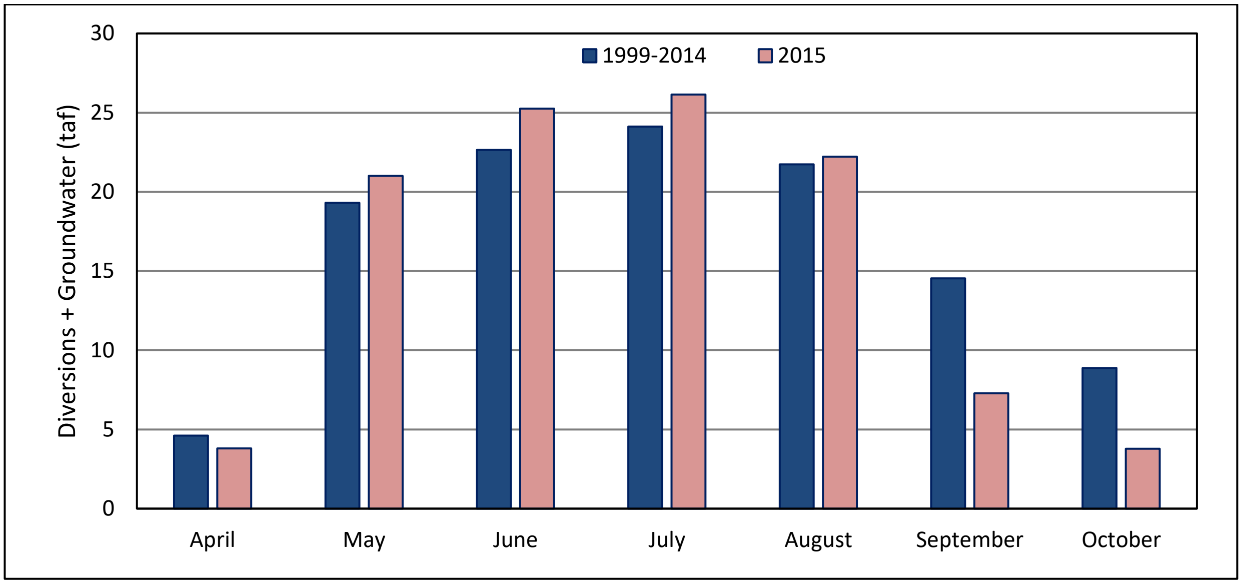

Figure 3. BWD April to October Diversions and Private Groundwater Pumping, 1999-2014 Average and 2015.

<u>Demand Impacts</u>

To illustrate impacts on demand caused by drought, demands for 2015 are summarized and compared to prior years. The years 1999 through 2014 represent years where the full surface water supply was available for diversion by BWD. The year 2015 represents a year in which the District's normal JWDB supply of 133,000 af was curtailed by 50%, representing an overall reduction of approximately 43% of BWD's JWDB supply due to the availability of an additional 8,750 af through the 1969 settlement agreement with the State, as described previously.

Average monthly estimated deliveries for BWD from 1999 to 2014 are shown in Figure 4, along with preliminary estimates of deliveries for April through October 2015. Total average deliveries between April and October were 67,000 af between 1999 and 2014 and 54,000 af in 2015.

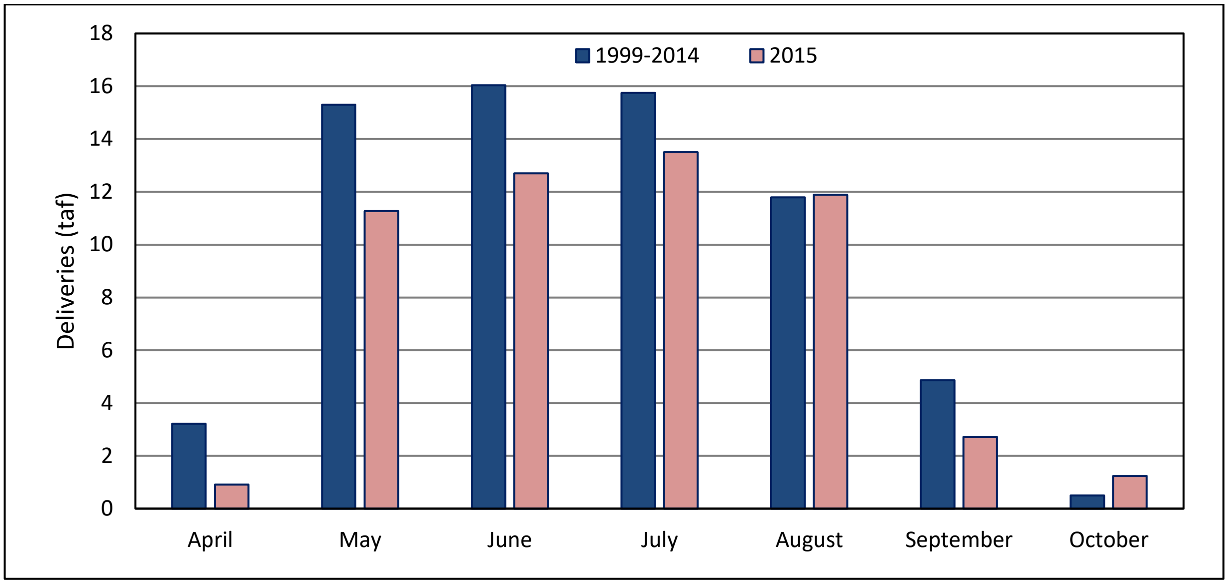

Figure 4. BWD April to October Deliveries, 1999-2014 Average and 2015.

References

DWR. 2015. A Guidebook to Assist Agricultural Water Suppliers to Prepare a 2015 Agricultural Water Management Plan. California Department of Water Resources.